التأثيرات البيئية لحرق النفايات الخطرة

محمد بن عثمان مليباري

قدمت هذه الرسالة استكمالا لمتطلبات درجة ماجستير العلوم

في العلوم البيئية

قسم العلوم البيئية

كلية الأرصاد والبيئة وزراعة المناطق الجافة

جامعة الملك عبد العزيز

جدة –المملكة العربية السعودية

١٤٢٠/٢٠٠٠م

إهداء

هذه الرسالة مهداة إلى

والديّ الحبيبين اللذين أوصلاني إلى هذه المكانة العلمية.

وإلى زوجتي العزيزة والحبيبة التي ساندتني ووقفت معي في أحلك الظروف.

وإلى والد ووالدة زوجتي العزيزين.

ملخص الرسالة

ازداد الاهتمام بصورة كبيرة في السنوات الأخيرة بموضوع التلوث البيئي الناجم عن حرق النفايات البلدية والكيميائية في أماكن ومواقد الحرق. وكنتيجة لذلك ، فقد تم وضع تغييرات ومقاييس مهمة لادارة النفايات بالطرق السليمة.

إن عملية الحرق هي عملية هندسية تستخدم التحلل الحراري خلال الأكسدة الحرارية عند درجة حرارة مرتفعة (٩٠٠م أو أكثر) وذلك لتكسير الأجزاء العضوية للنفايات و تقليل حجمها إلى جزيئات صغيرة. ان التصميم المناسب لانظمة المحارق يمكنها من تكسير النفايات الخطرة والتحكم بها.

ولقد اختيرت الشركة الوطنية للمحافظة على البيئة (بيئة) لعمل هذه الدراسة وهي شركة ذات ملكية سعودية تماما ، وقد أسست عام ١٩٨٨م بغرض التخلص من النفايات الصناعية والخطرة وهي تقع في مدينة الجبيل الصناعية بالمملكة العربية السعودية.

وقد جلبت شركة بيئة في عام ١٩٩٧م محرقة من نوع دوار مع متحكم ومنظف للغازات لمواكبة مقاييس جودة الهواء وهذا ما يسمى بمحطة حرق النفايات الخطرة.

والهدف الرئيسي لهذه الدراسة هي لتحديد الأثر البيئي الذي يتركه حرق النفايات الخطرة في هذه المحطة. وتتركز الأهداف الأخرى في دراسة مدى التأثير على جودة الهواء ونوعية بقايا الحرق (الرماد) التي تنتج من عملية الحرق. وقد تم تجميع معلومات من ملوثات الهواء والنفايات الداخلة للمحرقة وكذلك بقايا الحرق (الرماد) من شركة بيئة.

تم تحديد أنواع وكميات ملوثات الهواء الناتجة من المحرقة. وتم تجميع نتائج عينات ملوثات الهواء من شركة بيئة وقورنت مع مقاييس جودة الهواء. وتم عمل مقارنة لمتوسط نتائج تسعة أشهر بين إنبعاثات المداخن ومقاييس مصادر تلوث الهواء وقد أبرزت هذه المقارنة أن تراكيز أول أكسيد الكربون وثاني أكسيد الكبريت تقع في حدود مقاييس الهواء.

تم تميز أنواع وكميات النفايات الداخلة للمحرقة عن طريق الشركة. وتم تحليلها وتحليل بقايا الحرق (الرماد) في المختبر الخاص بالشركة. وتم عمل مقارنة لمتوسط نتائج تسعة أشهر بين النفايات الداخلة والرماد ووجد أن هناك تغير في تراكيز الكبريت والكلورين. وقد تم عمل مقارنة لمتوسط نتائج التسعة أشهر بين الرماد ومستويات أنظمة واجرائات خصائص السمية ووجد أن هناك ازديادا في تراكيز الكادميوم، الكروميوم، والرصاص ولكن وجد أن عناصر الأرسينيك، والزئبق في حدود المقاييس المعتمدة.

تم إجراء كذلك تجربة خاصة للمحرقة حيث تم تجميع عينة واحدة من النفايات الداخلة للمحرقة وعينة واحدة من بقايا الحرق (الرماد) وتم تحليلهما لمختلف العناصر الكيميائية والفيزيائية. وتم عمل مقارنة لهذه النتائج بين النفايات الداخلة والرماد ووجد أن هناك تغير في مستوى قلة الاحتراق وتراكيز مقياس الأس الهيدروجيني، المحتوى الرطوبي، الكلورايد، البوتاسيوم، السيليكا، الصوديوم، الكبريت، الأرسينيك، الزئبق، والزنك. وكذلك تم إجراء دراسة خاصة لحساب موازنة المواد لغرض إعطاء نبذة وفكرة عن النفايات الداخلة والخارجة للمحرقة.

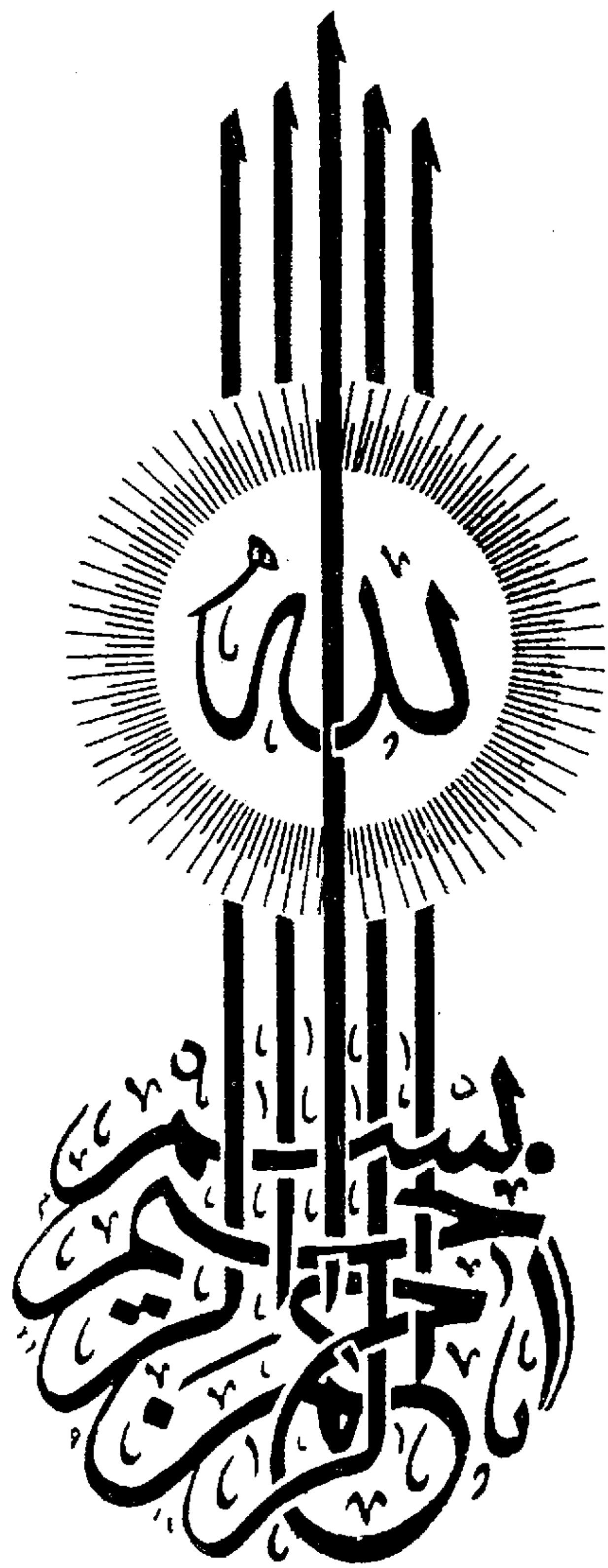
ENVIRONMENTAL IMPACTS OF HAZARDOUS WASTE INCINERATION

By
MOHAMMAD O. MELIBARI

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCES

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FACULTY OF METEOROLOGY, ENVIRONMENT AND ARID LAND AGRICULTURE
KING ABDULAZIZ UNIVERSITY
JEDDAH, KINGDOM OF SAUDI ARABIA

1420H-2000G


بسم الله الرحمن الرحيم

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We certify that we read this thesis and that in our opinions it is fully adequate in scope and quality as a thesis for the degree of
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ENVIRONMENTAL SCIENCES

Thesis Supervisor

Dr. Asad S. Abu-Rizaiza, Assistant Professor

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This thesis has been approved and accepted in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE
IN
ENVIRONMENTAL SCIENCES

Dr. M. Halit Goknil, Professor, Examiner

Dr. Khalil M. Al-Thagafi, Assistant Professor, Examiner

Dr. Asad S. Abu-Rizaiza, Assistant Professor, Examiner/Supervisor

ABSTRACT

Incineration is an engineering process that employs thermal decomposition via thermal oxidation at high temperature that usually 900°C or greater, in order to destroy the organic fraction of the waste and to reduce the volume.

The main objective of this study is to determine the environmental impact of incinerated hazardous waste. The specific objectives are concentrated on impact on the air quality and the types of residues (ash) that are generated through incineration process.

The National Environmental Preservation Company (BeeA'h) was selected to perform this study. It is a fully Saudi owned company established in 1988 to manage the disposal of industrial generated hazardous waste. It is located in Jubail Industrial City, Kingdom of Saudi Arabia. On 1997, BeeA'h has invested in a rotary kiln type incinerator with air emission control systems to meet air emissions standards known as the Hazardous Waste Incineration Facility. Data were collected for nine months period for air emissions, waste feed, and residues (ash).

The types and quantities of air pollutants emitted from the incinerator were identified. Findings were compared to emissions and air quality standards. Comparison of average results between Stack Emissions (Gas Concentrations) and air pollution source standards showed that CO and SO_2 concentrations were within the standards.

The types, quantities and characteristics of the waste fed and the residues (ash) resulted after incineration were identified through laboratory analysis at the facility. Comparison of average results between incineration waste fed and residues (ash) after incineration showed change in Sulfur and Chlorine concentrations. Also, comparison of the average results between residues (ash) and some of Toxicity Characteristic Leaching Procedure (TCLP) regulatory levels showed that increase in Cadmium, Chromium, and Lead concentrations, however; Arsenic and Mercury were below the regulatory levels.

Special experiment was performed for the mentioned incinerator where a one sample was collected from the waste fed before incineration, and one sample of the ash material after incineration for a one-time analysis. Results showed reduction in some concentrations. The material balance was calculated to provide an analysis of the subject incinerator system inputs and outputs.

المستخلص

إن عملية الحرق هي عملية هندسية تستخدم التحلل الحراري خلال الأكسدة الحرارية عند درجة حرارة مرتفعة (٩٠٠م أو أكثر) وذلك لتكسير الأجزاء العضوية للنفايات و تقليل حجمها إلى جزيئات صغيرة.

والهدف الرئيسي لهذه الدراسة هي لتحديد الأثر البيئي الذي يتركه حرق النفايات الخطرة. وتتركز الأهداف في مدى التأثير على جودة الهواء ونوعية البقايا (الرماد) التي تنتج من عملية الحرق.

ولقد اختيرت الشركة الوطنية للمحافظة على البيئة (بيئة) لعمل هذه الدراسة وهي شركة ذات ملكية سعودية تماما،وقد أسست عام ١٩٨٨م بغرض التخلص من النفايات الصناعية والخطرة وهي تقع في مدينة الجبيل الصناعية بالمملكة العربية السعودية. وقد جلبت شركة بيئة في عام ١٩٩٧م محرقة من نوع دوار مع متحكم ومنظف للغازات لمواكبة مقاييس جودة الهواء وهذا ما يسمى بمحطة حرق النفايات الخطرة. وقد تم تجميع معلومات لمدة تسعة أشهر من ملوثات الهواء والنفايات الداخلة للمحرقة وكذلك بقايا الحرق (الرماد) من شركة بيئة.

تم تحديد أنواع وكميات ملوثات الهواء الناتجة من المحرقة. وقد قورنت النتائج مع مقاييس جودة الهواء. وتم عمل مقارنة لمتوسط النتائج بين إنبعاثات المداخن ومقاييس مصادر تلوث الهواء وقد أبرزت هذه المقارنة أن تراكيز أول أكسيد الكربون وثاني أكسيد الكبريت تقع في حدود مقاييس الهواء.

وتم تمييز أنواع وكميات النفايات الداخلة للمحرقة وتحليلها وكذلك تحليل بقايا الحرق (الرماد) في المختبر الخاص بالشركة. وتم عمل مقارنة لمتوسط النتائج بين النفايات الداخلة والرماد ووجد أن هناك تغير في تراكيز الكبريت والكلورين. وقد تم عمل مقارنة لمتوسط النتائج بين الرماد ومستويات أنظمة واجرائات خصائص السمية ووجد أن هناك ازديادا في تراكيز الكادميوم، الكروميوم، والرصاص ولكن وجد أن عناصر الأرسينيك، والزئبق في حدود المقاييس المعتمدة.

وقد تم إجراء تجربة خاصة للمحرقة حيث تم تجميع عينة واحدة من النفايات الداخلة للمحرقة وعينة واحدة من بقايا الحرق (الرماد). وتم عمل مقارنة لهذه النتائج بين النفايات الداخلة والرماد ووجد أن هناك تغير في بعض التراكيز. وكذلك تم إجراء دراسة خاصة لحساب موازنة المواد لغرض إعطاء نبذة وفكرة عن النفايات الداخلة والخارجة للمحرقة.

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1. INTRODUCTION

1.1 HAZARDOUS WASTE INCINERATION

Over the last 15 years, concerns over improper disposal practices of the past has manifested itself in the passage of series level hazardous waste cleanup and control statutes of unprecedented scope. As a result, there has been a significant modification of waste management practices. The more traditional and low-cost methods of direct land filling, storage in surface impoundment and deep-well injection are being replaced in large measure by waste minimization at the source of generation, waste reuse, physical/chemical/biological treatment, incineration and chemical stabilization/solidification methods. Of all of the permanent treatment technologies, properly designed incineration systems are capable of the highest overall degree of destruction and control for the broadest range of hazardous waste streams. Substantial design and operational experience exists in this area and a wide variety of commercial systems are available. Consequently significant growth is anticipated in the use of incineration and other thermal destruction methods.

Increased concern has been expressed in recent years with regard to potential contamination of the environment as a result of the operation of municipal and chemical waste incinerators. In order to ascertain whether such concern is properly justified, it is necessary that measurements are made of various emissions sources, and the levels found should be compared with appropriate standards or accepted background levels. There are many potential sources of emissions from incinerators, but the most obvious is the chimney or stack. Other sources of equal or greater importance are water effluent, ash and fugitive emissions to air.

Incineration is an engineering process that employs thermal decomposition via thermal oxidation at high temperature (usually 900°C or greater) to destroy the organic fraction of the waste and to reduce the volume. Generally, combustible wastes or wastes with significant organic content are considered most appropriate for incineration. Technically, however, any waste with a hazardous organic fraction, no matter how small, is at least a functional candidate for incineration (Dempsey and Opplet 1993).

Incineration has been recognized as a very efficient process to destroy the industrial hazardous wastes (Lee, Huffman and Oberacker 1986). The hazardous waste is simply defined as a waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment. Incineration (or "thermal destruction") has been well recognized as one of the best demonstrated available technologies for waste destruction. Incineration is an engineering process, with waste destruction being the ultimate goal. Its function is to use either direct or indirect heat to break chemical structures of organic compounds, thus reducing the volume and toxicity of the remaining residuals (Lee, Huffman and Oberacker 1986).

From the engineering viewpoint, the basic objective of the incineration process is to efficiently combust the material to an ash that is acceptable for land disposal while assuring that the exhaust gas products can likewise be dispersed without harm to the environment. Secondary objectives are to carry out the process with minimun energy usage and minimum system maintenance costs (Nakhla 1992). Factors to be considered in evaluating waste for incineration are (Lee, Huffinan and Oberacker 1986):

- Dioxin/furan and Poly Chlorinated Biphyniles (PCB) content.

- Moisture content.
- Potential pollutants expected in incinerator effluents.
- Inert (ash) content.
- Heating value and auxiliary fuel requirements.
- Potential health and environmental effects of the effluents.
- Physical form.
- Corrosiveness.
- Known carcinogenic content.

In general, the heat content of the waste burned must maintain adequate ignition and incineration temperatures or a supplemental fuel must be provided (Lee, Huffman and Oberacker 1986).

Although incineration can destroy hazardous or toxic wastes, it also produces undesirable air pollutants, which requires procedures to be adopted to ensure clean discharges of combustion gases to the atmosphere. The undesirable pollutants may include (Lee, Huffman and Oberacker 1986):

- Hydrogen chloride (HCl) & other halogens.
- Particulates.
- Nitrogen oxides (NOx).
- Sulfur oxides (SOx).
- Products of Incomplete Combustion (PIC).
- Trace metals and their complexes.

To control these undesirable pollutants, an incineration system generally requires one or more Air Pollution Control Devices (APCDs) (Kim, Qi and Shaly 1994).

Incineration is thus far the best-demonstrated available technology for waste destruction. Unfortunately, it is not a perfect technology. It may emit unwanted products of incomplete combustion or trace metals. The Products of Incomplete Combustion could conceivably be equally or more hazardous than the original compounds in the waste fed to the unit. However, the amounts of the Products of Incomplete Combustion (PIC) in the exhaust are generally at least two orders of magnitude less than the original compounds in the feed. Both PIC and trace metal emissions are very complicated problem (Peary, Rowe and Tchobanoglous 1986).

The National Environmental Preservation Company (BeeA'h) was selected to perform this study. It is located in Jubail Industrial City and fully Saudi owned company established in 1988 to manage the environmental engineering of industrial and hazardous waste substances generated mainly by industry. BeeA'h has two state-of-the-art facilities for chemicals incineration and physical/chemical treatment and controlled disposal of hazardous materials.

Both facilities operate in accordance with Saudi national and local environmental standards (Meteorology and Environmental Protection Administration (MEPA) environmental regulations and Royal Commission (RC) Environmental Guidelines respectively). The treatment and disposal criteria used for both facilities are based on those of the United States Environmental Protection Agency (US EPA).

To safely dispose of organic hazardous wastes, thermal processing methods are required. To meet that end, BeeA'h has invested some SR50 million in Jubail Industrial City, in a high temperature processing facility (rotary kiln incinerator type and afterburner with emissions

scrubbing/control to meet proposed US EPA standards for air quality). This is known as the Hazardous Waste Incineration Plant.

The initially installed facility of BeeA'h is a Hazardous Waste Management Center and consists of a chemical treatment plant, solar treatment system, a double lined landfill, and a fully equipped laboratory for analysis of materials. The site operations and a system of six monitoring wells at different depths and locations around the site are independently monitored by MEPA and the RC to ensure that the facility operates to the highest standards of safety (BeeA'h Co. 1994).

1.2 OBJECTIVE OF THE STUDY

The main objective of this study is to determine the environmental impact of hazardous waste incineration in Jubail City, Saudi Arabia.

The specific objectives are concentrated on:

- Impact on air quality.
- Types of residues (solids) that are generated through incineration process.

2. LITERATURE REVIEW

2.1 INCINERATION METHODS

Combustion is a very complicated process. It involves complex interaction of heat and mass transfer, and chemical kinetics in a two-phase system. It is so complicated that many consider it as an art rather than a science. Applying already-complicated combustion theories to hazardous waste incineration makes the problem even tougher. The ultimate goal of hazardous waste incineration is to convert the hazardous materials into harmless combustion products (such as CO_2 and H_2O) that can be rejected directly to the atmosphere or removed by air pollution control devices when the combustion products are not totally harmless in themselves (Kim, Qi and Shaly 1994).

The type of waste feeder employed depends entirely on characteristics of the wastes to be incinerated. The factors that need to be considered in selecting a proper waste feeder include: waste physical form, gas, solids, liquids, sludge, ... etc.

Conventional speculation suggests that about 99 percent of wastes are destroyed in the flame zone of an incinerator, and that about 1 percent is destroyed in the post-flame zone. From a chemical point of view, incineration is an intensive oxidation process. Incineration or combustion basically refers to the rapid oxidation of organic substances. When oxidation is rapid, the temperature of the material rises rapidly due to transferring heat to the surroundings as rapidly as it is produced by the oxidation reaction. As a result, the material emits visible radiation, which is referred to as a "flame". A simplification of the overall chemical process that takes place during incineration is as follows:

Reactants		Products
$C + O_2$	$\rightarrow$	CO_2
$H_2 + 1/2\ O_2$	$\rightarrow$	H_2O

In actuality, these reactions seldom go to 100 percent completion. Consequently, numerous Products of Incomplete Combustion (PICs) can, and oftentimes do, form generally, however, in the ppm range (Dempsey and Opplet 1993).

The process of selecting and designing hazardous waste incineration systems can be very complex. Fortunately, considerable industrial manufacturing experience exists and many useful design guides have been published. Different incineration technologies have been developed for handling the various types and physical forms of hazardous waste. The four most common incinerator designs are liquid injection (sometimes combined with fume incineration), rotary kiln, fixed hearth and fluidized bed incinerators.

In addition, the four major subsystems, which may be incorporated into a hazardous waste incineration system, are:

(1) Waste Preparation and Feeding.

(2) Combustion Chamber(s).

(3) Air Pollution Control.

(4) Residue/Ash Handling.

That selection of the appropriate combination of these components is primarily a function of the physical and chemical properties of the waste stream or streams to be incinerated (BeeA'h Co. 1994).

(1) Waste Preparation and Feeding: The physical form of the waste determines the appropriate feed method. Liquids are blended, then pumped into the combustion chamber through nozzles or via specially designed atomizing burners. Wastes containing suspended particles may be screened to avoid clogging of small nozzle or atomizer openings. To incinerate lower heating value wastes supplementary fuel will normally be required. Blending may be achieved by either mixing the wastes before they are fed to the combustion chamber or by using separate nozzles for different types of waste, where the mixing occurs in the combustion chamber (Dempsey and Opplet 1993).

Sludge is typically fed using progressive cavity pumps. Bulk solid wastes may require shredding for control of particle size. They may be fed to the combustion chamber via rams, gravity feed, and airlock feeders, vibratory or screw feeders, or belt feeders (Dempsey and Opplet 1993).

(2) Combustion Chambers: The physical form of the waste and its ash content determine the type of combustion chamber selected. Most incineration systems derive their names from the type of combustion chamber employed.

Liquid injection incinerators or combustion chambers, are applicable almost exclusively for pumpable liquid waste. These units are usually

simple, refractory-lined cylinders (either horizontally or vertically aligned) equipped with one or more waste burners. Liquid wastes are injected through the burner(s), atomized to fine droplets and burned in suspension. Burners, as well as separate waste injection nozzles, may be oriented for axial, radial or tangential firing. Improved utilization of combustion space and higher heat release rates, however, can be achieved with the utilization of swirl or vortex burners.

Vertically downward oriented liquid injection incinerators are preferred when wastes are high in inorganic salts and fusible ash content, while horizontal units may be used with low ash waste. In the past, the typical capacity of liquid injection incinerators used to be roughly 30 x 106 Btu/h heat release. However, units as high as 210 x 106 Btu/h are now in operation (Kiang 1977).

Rotary kiln incinerators, are more versatile in the sense that they are applicable to the destruction of solid wastes, slurries and containerized waste as well as liquids. Because of this, these units are most frequently incorporated into commercial off-site incineration facility designs and utilized for Super fund remediation. The rotary kiln is a horizontal cylindrical refractory-lined shell that is mounted on a slight slope (see figure (1)). Rotation of the shell provides for transportation of waste through the kiln as well as enhanced mixing of the burning solid waste. The waste may move either concurrent or counter current to the gas flow. The residence time of waste solids in the kiln is generally 0.5 to 1.5 hours. This is controlled by the kiln rotation speed (typically 0.5 to 1.0 revolutions per minute). The feed rate is also generally adjusted to limit the amount of waste being processed in the kiln to at most 20 percent of the kiln volume (Dempsey and Opplet 1993).

The primary function of the kiln is to convert solid wastes to gases, which occurs through a series of volatilization, destructive distillation and partial combustion reactions. An afterburner is necessary, however, to complete the gas-phase combustion reactions. The afterburner is connected directly to the discharge end of the kiln where the gases exiting the kiln are directed to the afterburner chamber. Some more recent systems have installed a "hot cyclone" between the kiln and after-burner to remove solid particles that might otherwise create slogging problems in the afterburner. The afterburner itself may be horizontally or vertically aligned, and essentially functions much on the same principle as a liquid injection incinerator. In fact many facilities also, fire liquid hazardous waste through separate waste burners in the afterburner. Both the afterburner and kiln are usually equipped with an auxiliary fuel firing system to bring the units up to temperature and to maintain the desired operating temperatures. On the other hand, some operators' make it a practice of firing their aqueous waste streams into the after-burner as a temperature control measure. Rotary kilns have been designed with a heat release capacity as high as 150 x 10^6 Btu/h in the United States. On average, however, units are typically around 60 X 10^6 Btu/h (Dempsey and Opplet 1993).

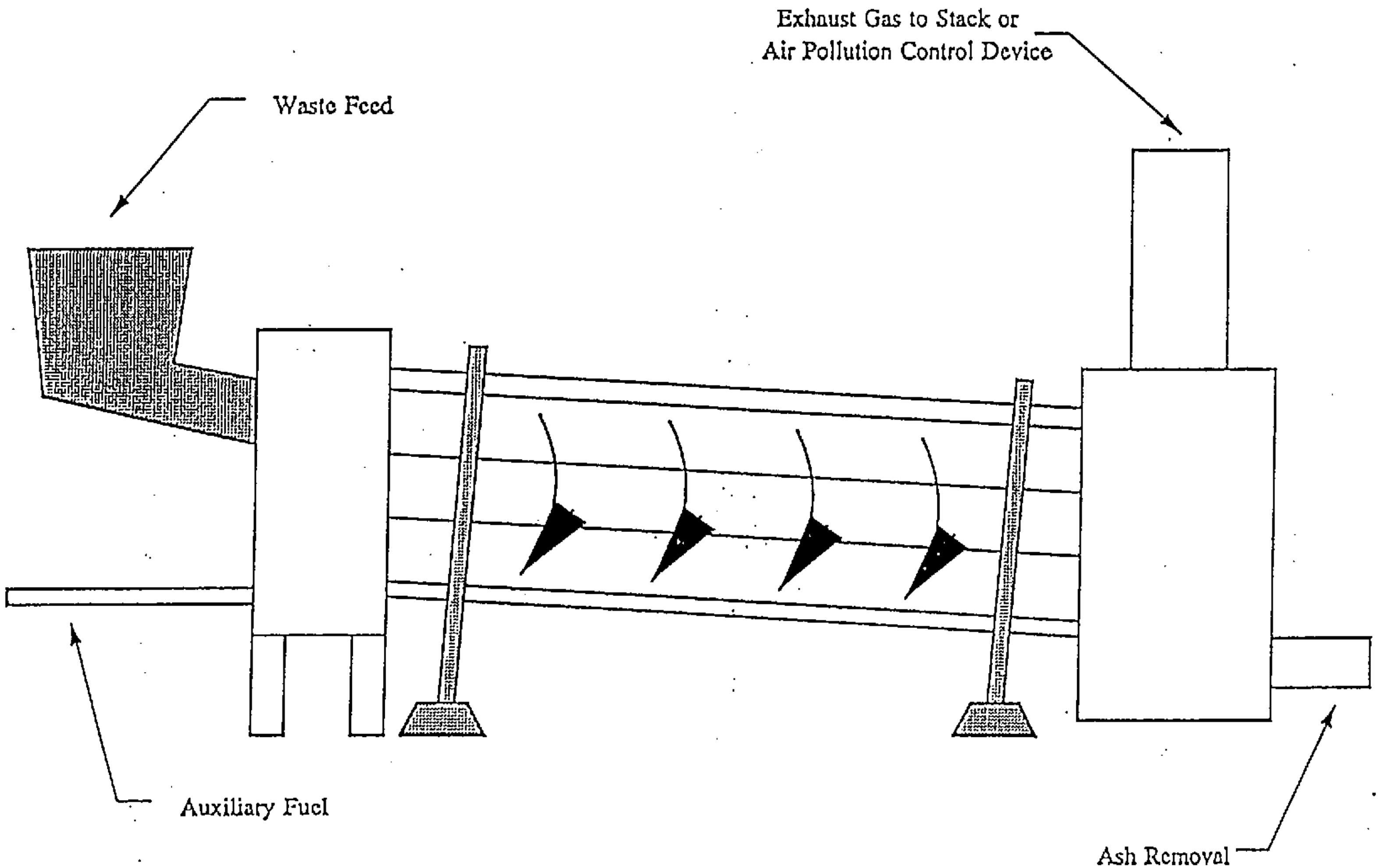


Figure (1): Rotary Kiln Incinerator.

Fixed hearth incinerators, also called controlled air, starved air or pyrolytic incinerators, are the third technology in use for hazardous waste incineration today. These units employ a two-stage combustion process, much like rotary kilns. Waste is pumped into the first stage or primary chamber, and burned at roughly 50 to 80 percent of Stoichiometric air requirements. This starved air condition causes most of the volatile fraction of the waste to be vaporized by the endothermic heat provided by the oxidation of the fixed carbon fraction. The resultant smoke and pyrolytic products consisting primarily of methane, ethane and other hydrocarbons; carbon monoxide and products of combustion pass to the second stage, or secondary chamber. Here, additional air is injected to complete the combustion, which can occur either spontaneously or through the addition of supplementary fuels. The primary chamber combustion reactions and turbulent velocities are maintained at low levels by the starved-air conditions to minimize particulate entertainment and carryover. With the addition of secondary air, total excess air for fixed hearth incinerators is in the 100 to 200 percent range.

Fixed hearth units tend to be of smaller capacity than liquid injection or rotary kiln incinerators because of physical limitations in ram-feeding and transporting large amounts of waste material through the combustion chamber (Dempsey and Opplet 1993). These lower relative capital costs and potentially reduced particulate control requirements make them more attractive than rotary kilns for smaller on-site installations.

Fluidized beds incinerators, have long served the chemical processing industry as a unit operation and have been used to burn sludge generated by municipal wastewater treatment plants. This type of combustion system has only recently begun to see application in hazardous waste incineration.

Fluidized bed incinerators may be either circulating or bubbling bed designs. Both types consist of a single refractory-lined combustion vessel partially filled with particles of sand, alumina, calcium carbonate or other such materials. Combustion air is supplied through a distributor plate at the base of the corn at a rate sufficient to fluidize (bubbling bed) or entrain part of the bed material. In the design, air velocities are and the solids are blown overhead, separated in a cyclone and then returned to the combustion chamber. Operating temperatures are normally maintained in the 1,400^{o}F (760^{o}C) to 1,600^{o}F (871^{o}C) range and excess air requirement range from 25 to 150 percent (Rickman, Holder and Young 1985).

Fluidized bed incinerators are primarily used for liquids, sludge or shredded solid materials including soil. To allow for good distribution of waste materials within the bed and removal of solid residues from the bed, all solids generally require prescreening or crushing to a size less than 2 inches in diameter. Fluidized bed incinerators, offer high gas-to-solids ratios, high heat transfer efficiencies, high turbulence in both gas and solid phases, uniform temperatures throughout the bed, and the potential for in-situ acid gas neutralization by lime, limestone or carbonate addition (Rickman, Holder and Young 1985).

Regardless of the incinerator type selected, the chemical and thermally named properties of the wastes determine the sizing of the combustion chamber and its operating conditions (temperature, excess air, and flow rates) and determine the nature of air pollution control and ash/residue handling systems. Elemental composition and moisture content data are necessary to determine Stoichiometric combustion air requirements and to predict combustion gas flow and composition. These parameters are

important in determining combustion temperature and residence time, the efficiency of waste, fuel/air mixing, and the type and size of air pollution control equipment (Dempy and Opplet 1993). It is important to understand, however, that significant deviation from these values has been observed in actual field practice without detrimental effect on waste destruction and removal efficiency.

(3) Air Pollution Control: Following the incineration of hazardous wastes, combustion gases typically need to be further treated in an air pollution control system The presence of chlorine or other halogens in the waste will generally signal a need for a scrubbing or absorption step for combustion gases to remove HCl and other acids. Ash in the waste is not destroyed in the combustion process. Depending on its composition, ash will either exit as bottom ash, at the discharge end of a kiln or hearth for example; and/or as particulate matter suspended in the combustion gas stream (fly ash). Particulate emissions from most hazardous waste combustion stems generally, have particle diameters down to less than one micrometer and require high efficiency collection devices to meet the government emission standards (Dempsey and Opplet 1993).

One of the most commonly employed Air pollution control Systems for hazardous waste facilities is a quench (gas cooling and conditioning) followed by high-energy venturi scrubber (particulate removal), a packed tower absorber (acid gas removal), and a demister (visible vapor plume reduction). Facilities handling low ash, low halogen content liquid waste streams have been able to operate without any control, however; many designs have begun to incorporate waste heat boilers as a substitute for gas quenching and as a means of energy recovery. This is largely due to their

high removal efficiencies for small panicles and lower pressure drop (Dempsey and Opplet 1993).

Venturi scrubbers involve the injection of a scrubbing liquid (usually water or a water/caustic solution) into the exhaust gas stream as it passes through a high velocity constriction. The liquid is atomized into fine droplets, which entrain fine particles and a portion of the absorbable gases in the gas stream. The major advantage of Venturi scrubbers is their reliability and relative simplicity of operation. On the other hand, maintaining the significant pressure drop across the Venturi throat (60 to 120 inches of water column) is required for efficient hazardous waste combustion, particulate matter control represents a significant percentage of the cost of operation of incineration facilities employing Venturi scrubbing. Also, Venturi scrubbers may not be very effective in controlling the emission of fine Particulates such as metal aerosols (Dempsey and Opplet 1993).

Acid gas removal is generally accomplished in packed bed or plate tower scrubbers. Packed bed scrubbers are generally vessels filled with randomly oriented packing material such as polyethylene saddles or rings (Dempsey and Opplet 1993).

The scrubbing liquid is fed to the top of the vessel, with the gas flowing in either concurrent, countercurrent or cross-flow modes. As the liquid flows through the bed, it wets the packing material and thus provides the interfacial surface area for mass transfer with the gas phase, which is required for effective acid gas absorption (Dempsey and Opplet 1993).

Like packed bed scrubbers, plate scrubbers also rely on absorption for the removal of contaminants. The basic design is a vertical cylindrical column with a number of plates or trays inside. The scrubbing liquid is introduced at the top plate and flows successively across each plate as it moves downward to the liquid outlet at the tower bottom. Gas comes in at the bottom of the tower and passes through openings in each plate before leaving through the top. Gas absorption is promoted by the breaking up of the gas phase into small bubbles, which pass through the volume of liquid on each plate.

Packed bed or plate tower scrubbers arc commonly used at liquid injection incinerator facilities, where absorption of soluble gaseous pollutants (HCl & SO_x) is often most important and particulate control is less critical (Dempsey and Opplet 1993). At rotary kiln or fixed hearth facilities, or liquid injection facilities where high ash content wastes are incinerated, however, Venturi scrubbers are often used in series with packed bed or plate tower scrubbers.

(4) Residue and Ash Handling: The inorganic components of hazardous wastes are not destroyed by incineration (Dempsey and Opplet 1993). These materials exit the incineration system either as bottom ash from the combustion chamber, as contaminants in scrubber waters and other air pollution control residues, and in small amounts in air emissions from the stack. Residues generated from the incineration of hazardous waste must be managed carefully.

Ash is commonly either air-cooled or quenched with water after discharge from the combustion chamber. From this point, ash is frequently

accumulated on-site in storage lagoons or in containers prior to disposal in a permitted hazardous waste land disposal facility. Dewatering or chemical fixation/stabilization may also be applied to meet the regulation standards prior to disposal (Dempsey and Opplet 1993).

Air pollution control residues are generated from the combustion gas quenching, particulate removal, arid acid gas absorption steps in an incineration system. These residues are typically aqueous streams containing entrained particulate matter, absorbed acid gases (usually as HCl), salts, and trace amounts of organic contaminants. These streams are often collected in sumps or recirculation tanks where the acids are neutralized with caustic and returned to the process. Eventually, a portion or all of these waters must be discharged for treatment and disposal. Many facilities discharge neutralized waters to settling lagoons or to a chemical precipitation step to allow for suspended contaminants to be concentrated and ultimately sent to land disposal. Depending upon the nature of the dissolved contaminants and their concentration after treatment, waters may either be returned to the process or discharged to sewers. One alternative to the management of aqueous residue streams is to use dry scrubber systems, which, do not generate any wastewater (Dempsey and Opplet 1993).

2.2 EFFECTS OF INCINERATION ON ENVIRONMENT

Regardless of the apparent capabilities of hazardous waste incinerators to meet or exceed the regulation performance standards, the ultimate public test involves demonstration that there is no unacceptable increase in public health risk from the emissions to the environment (Dempy and Opplet 1993). While any of the emissions from an incinerator may potentially be of environmental interest, most attention; has been directed

toward air pollution emissions. This is because they appear to represent the most important source of off-site human exposure and there is no opportunity for secondary containment or treatment of emissions once they leave the stack. and scrubber residues, however, are lower in volume and can be contained, examined and if necessary, treated prior to discharge or disposal. In addition to chronic exposure to recurring emissions, there are also environmental and public health impacts, which could result from potential single-event or catastrophic emissions at incineration facilities (Dempsey and Opplet 1993).

Risk assessment and risk management have been used increasingly by industry and government over the past fifteen years in evaluating control technology and regulatory options for managing hazardous waste. The initial 1978 Resource Conservation Recovery Act (RCRA) incineration standards, for instance, were almost entirely designed and were performance oriented. In the 1981 proposal, however, United States Environmental Protection Agency (US-EPA) incorporated risk assessment into what was called the 'Best Engineering Judgment" (BEJ) approach to regulating and permitting incinerators. The operating and performance standards for incinerators were to apply to facilities unless a site-specific risk assessment indicated that a higher degree of control was necessary. Risk assessment and cost-benefit analysis became a more integral part of the development of hazardous waste control technology standards.

Rules promulgated for burning hazardous waste in boilers and industrial furnaces require that emissions testing and health-risk assessments for chlorinated dioxins and furans for certain facilities be done. Emission limits for metals, HCl and Cl_2 are based on projected inhalation health risks to the hypothetical maximum exposed individual. Similar approaches were

used in developing the proposed amendments to the hazardous waste incinerator regulations.

Without doubt, the greatest amount of scientific and public attention has been given to one class of incinerator combustion byproducts, the dioxins and furans. Dioxins are members of a family of organic compounds known chemically as dibenzo-p-dioxins. This family is characterized by a three-ring nucleus consisting of two benzene rings interconnected by a pair of oxygen atoms. Usually, the term "dioxin" refers to the chlorinated congeners of dibenzo-p-dioxin. Theoretically, one to eight chlorine atoms can occur at dioxin substituent positions such that 75 chlorinated dioxin congeners are possible (Keating 1986).

Furans are members of a family of organic compounds known chemically as dibenzofurans. They have a similar structure to the dibenzo-p-dioxins except that the two benzene rings in the nucleus are interconnected with a five-member ring containing only one oxygen atom. As with dioxins, the term "furan" normally refers to the chlorinated congeners of dibenzofurans. Theoretically, 135 chlorinated furan congeners are possible. From a human health hazard viewpoint, the polychlorinated dibenzo-p-dioxin (PCDD) and the polychlorinated dibenzofuran (PCDF) compounds (specially, their "tetra" and "penta" forms) are the most significant. Polychlorinated, as used here, means the compound contains four or more chlorine atoms (Keating 1986).

Polychlorinated dibenzo-para-dioxins (PCDDs) and polychlorinated dibenzo-furans (PCDFs) are often simply called as dioxins, although, actually they are two separate group of substances with similar effects. They comprise altogether 210 (75 PCDDs & 135 PCDFs) different chemical

compounds, of which twelve "The Dirty Dozen" are especially toxic (Jones, Pettit and Hillmer 1994).

Dioxins may be formed through almost any process of combustion, as well as in other ways. Major sources of dioxin emissions based on limited investigations could be outlined as follows:

- Incinerators (flue gases).
- Motor Vehicles (exhaust gases).
- Iron, Steel, and non-ferrous metal works (flue gases).
- Pulp and paper mills (flue gases, effluents).
- Coal fired power plants (flue gases).
- Hospital furnaces (flue gases).
- Burning of Hazardous Wastes (flue gases).

Other sources of dioxins emissions are oil wastes and the burning of such wastes, diesel driven vehicles, certain kinds of chemical manufacturing, non-liquid wastes and sludge.

For risk assessment purposes, EPA currently classifies 2,3,7,8-PCDD as a "B2" carcinogen, by far the most potent carcinogen yet evaluated by the Agency. The B2 category is one of five categories that EPA uses to group the weight of evidence of the carcinogenicity of a chemical for humans. These are further defined as follows (USEPA 1985):

Group A: There is sufficient evidence from epidemiological studies to support a causal association between exposure to the chemical agent and cancer.

Group B1: The weight of evidence of carcinogenicity based on animal studies is "sufficient" but there is limited evidence of carcinogenicity from epidemiological studies.

Group B2: The weight of evidence of carcinogenicity based on animal studies is "sufficient" but there is "inadequate evidence" or "no data" from epidemiological studies.

Group C: There is limited evidence of carcinogenicity in animal studies but no human data.

Group D: Not classified as to human carcinogenicity because there is inadequate human and animal evidence of carcinogenicity or no data available.

Group E: Not a human carcinogen.

Dioxins are highly toxic potential human carcinogens. Exposure to PCDD contaminated materials may cause a severe and disabling acne like rash that may persist for years, metabolic disorders, and nervous system and liver damage. In animals, PCDD causes teratogenesis, tumorigenesis, and immunological dysfunction. Findings in human are inconclusive, but human toxicology is under continuing investigation (Dempsey and Oppelt 1993).

Furan may be absorbed via inhalation, skin, or ingestion. It vapors are skin, eyes and mucous membranes irritants. Burning and watering eyes may be noted at low airborne concentrations. Furan is a Central Nervous System (CNS) depressant that may cause respiratory arrest and death with sufficient

exposure. This material is considered a constituent of the cigarette smoke felt to cause paralysis (Jones, Pettit and Hillmer 1994).

With the exception of analytical standards, dioxins and furans are not intentionally made for any purpose. They can, however, be created as by products in the manufacture of other chemicals (such as some pesticides) or as a result of incomplete combustion or the recombination of exhaust products from the burning of mixtures containing certain chlorinated organic compounds. Since the first published report of PCDD and PCDF emissions from a municipal solid waste incinerator by a large number of studies have been carried out to examine this phenomenon (Dempsey and Oppelt 1993).

A large part of the interest has been placed on municipal solid waste incineration. A number of excellent summaries of municipal solid waste incinerator emission data have been prepared. EPA has reviewed PCDD and PCDF emissions data for a broad range of combustion sources, including fossil fuel and wood combustion and a wide range of industrial furnaces, and has reported the results of emissions testing at 13 additional facilities (USEPA 1987).

Recent testing has demonstrated, however, that through the combination of good combustion practices and flue gas cleaning, dioxin/furan emissions, can be dramatically reduced to levels that are about the same as to somewhat higher than those reported for hazardous waste incinerators (Dempsey and Oppelt 1993).

From a human health risk viewpoint, the mass of toxicity equivalents emitted is the best indication of the threat posed by these emissions.

Using an even more conservative approach, risk assessment calculations for dioxin/furan emissions from two HWIs burning PCBs concluded that these emissions did not pose a significant risk. Dioxin/furan emissions levels from these two facilities are at the high end of the range of emissions measured from hazardous waste incinerators. The lower levels of emissions found at other facilities burning hazardous waste are not believed to create a significant risk to human health (USEPA 1981).

The level of dioxin emissions from a wide range of combustion-related processes is examined, but discussion focuses specifically on industrial waste incinerators, and attempts to place these into proper perspective when compared to other sources of emissions. Measurement methods are discussed together with the present philosophy on the control of dioxin emissions, and the human risk due to the global dioxin is estimated (Jones, Pettit and Hillmer 1994).

Municipal Waste Incinerators (MWIs): There are atmospheric emissions of PCDDs and PCDFs from municipal waste incinerators. The emissions depend less on the nature of the waste, but more on the combustion efficiency and the quality of the stack gas cleaning, and may depend on the design of the incinerator. When incinerators are equipped with multistage stack gas cleaning procedures and electrostatic precipitators, the emission levels attain modern standards.

The goal for PCDD and PCDF emission acceptable levels will necessitate the development of new and costly technologies. It has been suggested that emissions at these low levels may be attained by optimization

of the combustion process and use of appropriate flue gas cleaning devices (Kilgore, Nelson and Lanier 1990).

Emission via other routes: Flue gas, fly ash, sludge and water emission streams may also contain PCDDs and PCDFs.

Industrial Waste Incinerators (IWIs): Both the number of industrial waste incinerators and the quantity of waste incinerated are substantially lower than for municipal waste incinerators. Industrial waste incinerators are designed to provide maximum efficiency of waste destruction through ensuring that the following parameters are optimized:

- Waste preparation and loading rate.
- Residence time.
- Turbulence.
- Temperature.
- Waste/oxygen ratio.

Ensuring very thorough mixing of the fuel/waste with oxygen is one of the most important factors. Temperature itself is not the most important parameter, provided that a minimum temperature of 870^0C is achieved. It is claimed that reaction kinetics of oxidation are not the limiting factor above such temperatures, and that the level of excess oxygen and temperature can only add small improvements once thorough waste/fuel and oxygen mixing have been achieved. Industrial waste incinerators commonly employ two-stage combustion with a secondary combustion charger in order to provide greater residence time and improved turbulence through the physical design of this stage. The use of excess oxygen helps to overcome deficiencies in waste/fuel - oxygen mixing, although it has been demonstrated that increased oxygen raises the yield of PCDFs during combustion when other

parameters are held constant. In practice, however, attempts are made to optimize the advantages of all the above parameters.

Increased levels of PCDDs and PCDFs through reformation reactions, or called denovo synthesis, may be minimized when (Acharya, Decicco and Novak 1991):

- No secondary heat recovery is used.
- Rapid quenching - such as by the wet process is used.
- Known precursors for PCDDs and PCDFs are not incinerated.

There are atmospheric emissions of PCDDs and PCDFs from industrial waste incinerators. Although the wastes in industrial incinerators normally contain more precursor substances than municipal waste, the concentrations of PCDDs and PCDFs emitted from industrial waste incinerators are substantially lower than those from older municipal waste incinerators, and generally still lower than those of the most advanced municipal waste incinerators.

Emissions via other route, Sludge and wash water have been examined for PCDDs after burning chlorine-containing wastes in the industrial waste incinerator. It should be noted, however, that PCDDs and PCDFs present in slag, ash and wastewater would generally have low mobility and tendency to disseminate into the environment.

Dioxin containing wastes specified in the US-EPA Hazardous Waste are prohibited from land disposal except under certain conditions, if the waste in contaminated soil and debris resulting from a response action taken under section 104 or 106 of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) or a corrective action

taken under subtitle C of the Resource Conservation and Recovery Act (RCRA).

Methods for obtaining representative ash samples from bulk quantities of material ultimately depend on statistical methods of dividing a large quantity of non-uniform material into smaller portions, which may be reasonably representative of the whole. Following collection of a representative ash sample, it is usual to recover trace organic such as dioxins by simple Soxhlet extraction, and to analyze the extract by an appropriate combination of chromatography and mass spectrometry. Guidance regarding suitable effluent concentrations may be obtained by examining the background levels of dioxins, which are typically found in soils. Background soils are a relevant reference point, since the likely fate of ash from incineration is to be disposed of by landfill.

Once more, very few measurement data for the concentration of dioxins in ash from incineration processes are available, although very wide ranges of dioxins in differing ash samples have been observed (Jones, Pettit and Hillmer 1994).

Municipal Solid Waste (MSW) incinerator fly ash is also considered as toxic waste because of its high content of heavy metals and dioxins. Such plants can be conveniently re-engineered into existing MSW-incinerators, thus reducing investment costs by using existing infrastructures and off-gas systems (Hoffelner 1990).

Bottom ash is the result of the MSW incinerator of household and industrial wastes. It constitutes 75-95% of incineration ash, the remainder being fly ash, flue-gas purification residues (filter cake) and various salts.

Every MSW incineration plant has its own particular problems and requirements, depending on the quality and extent of upgrading of its raw bottom ash. The process can entail merely screening unburned materials and deferrization, or using more advanced separation methods to remove non-ferrous metals (Duijn and Bunnik 1990).

Bottom ash is an excellent secondary building material for earth and road works, despite the high environmental standards it has to meet. For instance, the ash must entirely incinerated and deferred, while all particles larger than 40 mm has to be removed. Arsenic, cadmium, chromium, copper, nickel, lead and zinc levels must be below certain limits to avoid leaching. In addition, it must be possible to recover buried bottom ash; the top and sides of the ash layer have to be sealed with a waterproof coating and the bottom layer cannot be less than 50 cm above the average highest groundwater level (Duijn and Bunnik 1990).

Bottom ash is simply dumped in landfills, for both economic and political reasons, In most countries, when less expensive natural building materials, such as gravel and sand, are available, secondary building materials such as bottom ash are usually avoided (Duijn and Bunnik 1990).

Upgrading may also be attractive for political reasons, such as subsidy schemes, requirements related to the use of certain percentage of bottom ash in earth and road works, and a ban on dumping bottom ash in landfills. The profitability of upgrading bottom ash can vary from country to country and even region to region. Wherever the economic policy can lead to optimum recycling (Duijn and Bunnik 1990).

The major sources of atmospheric contamination by PCDDs and PCDFs at the present time are municipal and hospital waste incinerators, metallurgical processes and possibly coal combustion (Jones, Pettit and Hillmer 1994).

Atmospheric PCDDs and PCDFs emitted from all sources are deposited on soil, grass, and vegetation and surface water. Subsequent uptake by animals and bioaccumulation make the food chain the most important route of exposure for humans, fish, dairy produce, meat products and vegetables are all-important. Because of mother's milk contamination, higher food intake in respect to body weight, and the large proportion of dairy products consumed by children, their body burden may be expected (Jones, Pettit and Hillmer 1994).

Based on a combination of experimental toxicology and epidemiological data, an assessment has been made of the health risk to humans resulting from such exposure. In humans the only clearly established toxic effect of these compounds is chlorine. Data on other effects including cancer are inconclusive, and remain a controversial issue. By applying a safety factor of 100, it can be assumed that humans would not be affected by a lifetime exposure to PCDDs and PCDFs. Thus the total uptake of PCDDs and PCDFs from all known sources humans is within the range for this tolerable daily intake (Jones, Pettit and Hillmer 1994).

Waste incineration has been the prominent source of dioxins. Through a combination of good combustion practices and flue gas cleaning, dioxin/furan emission from MWIs can be dramatically reduced to levels that are about the same as to somewhat higher than those reported for hazardous waste incinerators. It is expected that current efforts to develop emission

standards for MWIs may also result in design and operational improvements, which will effect a reduction of dioxin/furan emissions from these facilities as well (Jones, Pettit and Hillmer 1994).

Metals in incineration, which under normal landfill conditions might not leach, may be released to the environment when burned in an incinerator. Of the products affected by the toxics statute, this is particularly true with plastics. Heavy metals cannot be destroyed in an incinerator. They must exit or accumulate within the unit. Most of the metals will remain in the bottom ash, a portion become gases and exit with the flue gases. The metals may attach themselves to the particulate matter in the flue gases and some will be captured in the flue gas cleaning equipment (Brunner 1989).

As a metal, mercury persists in the environment. It is difficult to destroy by burning or bacterial breakdown and in bioaccumulates in the body. Mercury can easily exist as a vapor, so it can be inhaled and absorbed into the blood. It affects a variety of internal organs and methyl mercury, an organic form of mercury, affects the central nervous system (USEPA 1998).

Cadmium does not break down in the environment, but it can change forms, some of which dissolve in water. Dissolved cadmium can bioaccumulate up the food chain. The USEPA had classified cadmium as a probable human carcinogen. The two main routes of exposure for the general population are by inhalation of cadmium particles and ingestion of food or water containing cadmium. Most cadmium in the environment is in the form of particulate matter in the air and is generated from human activities such as mining, smelting, fuel combustion and incineration of waste or sewage sludge. Cadmium entering the body is excreted slowly over time, but too much cadmium can overload the kidneys and cause damage.

Cadmium is a cumulative toxin, so long-term exposure at an elevated level is a concern. At higher levels of exposure, calcium deficiencies and bone disorders have been reported, but effects on bones generally appear only after the kidneys have been damaged. Limited evidence exists for an association between inhalation exposure to cadmium and reproductive effects (USEPA 1998).

Inhalation is the main pathway of exposure for people whose occupation exposes them to lead particles. There is no beneficial purpose for lead in the human body. Lead has been shown to affect virtually every major organ in the body. The most sensitive organs appear to be the nervous system (particularly in children), the circulatory system and the cardiovascular system (USEPA 1998).

There are three routes of exposure for hexavalent chromium, inhalation of airborne particles, ingestion, and to a much lesser extent, through the skin. For the general population, the most common route of exposure is by eating foods containing hexavalent chromium. Only very small amounts of hexavalent chromium can enter the body through the skin unless the skin is damaged (USEPA 1998).

3. METHOD OF DATA COLLECTION

A general survey of waste incineration was conducted at the cited company, National Environmental Preservation Co. BeeA'h in order to evaluate the environmental effects of hazardous waste incineration. This includes the following:

- Description of BeeA'h company Plant.
- Air analysis methods.
- Wastes analysis methods.

3.1 DESCRIPTION OF BEEA'H COMPANY PLANT

The BeeA'h incinerator process incorporates four key steps. First is feed preparation, a critical step for all that follows. Step two is the actual incineration process. Scrubbing and cleaning of the gases formed in the combustion process follows and residual ash disposal is the final step.

The incinerator at the BeeA'h has two separate firing chambers see figure no. (2). The first is the rotary kiln (primary combustion chamber), where all solids, sludge and hazardous liquids are fed. The rotary kiln is 3 m diameter by 10 m long. It is refractory lined with a combination of insulating and abrasion-corrosion resistant. Kiln temperatures typically in the range of 930^0C to 960^0C. The kiln operates in dry ashing mode, so the upper end of the temperature range must be controlled to prevent unwanted slag formation. The Secondary Combustion Chamber (SCC) is an updraft, vertical refractory lined chamber. It is sized such that the combustion gases are retained in it for a minimum of two seconds to allow sufficient time for complete combustion to take place. Temperature throughout the chamber is

maintained in excess of 1100^0C and over 1200^0C for PCB processing. Final destruction of the hazardous organic waste occurs in this chamber.

Both the rotary kiln and secondary chamber are equipped with dual fuel burners, which permit the simultaneous firing of both energetic wastes and supplementary liquid fuels. In addition, the rotary kiln front wall is equipped with a sludge injection port and a solids ram feeder.

Residual ash is discharged from the kiln to a drag chain conveyor, which transfers the residues to enclose steel bins. The design characteristics could be achieved for:

- Organic Liquid Wastes is 750 kg/hr.
- Solid Wastes is 1200 kg/hr.
- Sludge Wastes is 1000 kg/hr.
- Total Chlorine is 300 kg/hr.
- Polychlorinated biphenyl's (PCBs) is 50 kg/hr.

Feed preparation begins with a review of the physical and chemical characteristics of the wastes, followed by a plan for their pre-treatment. Bulk wastes can be directly transferred to storage tanks, or in the case of solids to a concrete bunker. Drummed wastes entering the feed preparation building are directed to one of three areas. The waste types are fed to the hazardous waste incineration system through three waste feed systems:

- Liquid waste feed system.
- Solid waste feed system.
- Sludge waste feed system.

Each of these feed systems has been designed to handle material in a wide range of physical and chemical properties. The combination of the three systems allows material of virtually any form except gasses to be handled and fed the hazardous waste incineration.

The liquid waste feed system consists of the following components; a tank farm area, blend\feed tanks, feed\transfer pumps, and agitators. Liquid waste is transferred from the tank farm to the blend\feed tank. The blend\feed tanks are equipped with agitators and baffles for thorough mixing of the tank contents. Waste flows from the blend\feed tanks to the feed pumps. The feed pumps are centrifugal pumps that can feed waste to either the rotary kiln liquid waste burner or the SCC liquid waste burner. However, PCB wastes are fed only to the rotary kiln liquid waste burner. Strainers are provided in the liquid waste feed lines to prevent oversized solids from entering and possibly plugging the burner nozzles.

The solid waste feed system provides the means for transferring solid waste and containerized (solid) waste into the rotary kiln. Solid waste is transferred from waste shipping containers to solids feed bins, fiber drums, or plastic drums. Waste placed into the solids feed bins is routed to the bin dumper. The bin dumper elevates and inverts the bins and discharges the bin contents into the rotary kiln ram feed hopper. The hydraulic ram of the ram feeder drives the solids in the hopper into the rotary kiln. Fiber drum or plastic drums containing solid waste are placed on a manually adjustable conveyor that transfers the drum to the rotary kiln ram feeder hopper. The hydraulic ram of the ram feeder drives the solids in the hopper into the rotary kiln. The ram feeder is equipped with an air lock system to control fugitive emissions and fire suppression. The bin feed system and the drum

feed system are interlocked such that only one system can be operated at any time.

Wastes that are difficult to handle by either the solid waste feed system or the liquid waste feed system are handled by the sludge waste feed system. The sludge storage and blending bin receives sludge from trucks or bins. The sludge storage bin is equipped with live bottom screws that agitate the waste to the bottom corner of the bin discharge through a gate valve to the positive-displacement sludge feed pump. The feed pump injects the wastes into the rotary kiln through a sludge lance.

The drummed liquid go to the decant area, where vacuum pumps are used to decant liquids from drums to day tanks. From there, the liquids are pumped to 30m stainless steel storage tanks. Drummed solids are also directed to the repackaging area for transfer. The kiln solids feed system can accommodate full 200-liter plastic drums. However, high heat content wastes are normally repacked into smaller lots to assure even thermal loading in the kiln. Drummed sludge are screened and transferred to bulk containers, or conveyed directly to the sludge feed tank. Residual solids from sludge drums are re-packaged and fed to the kiln through the solid feed system. All drums, once emptied are cleaned then recycled, or transferred to the landfill for final disposal.

The air pollution control system that are, hot gases from the secondary combustion chamber pass through a refractory lined cyclone (see figure (2)). Coarse particulate are separated and discharged to the ash conveyor. The flue gases then split and a small fraction (20%) are directed to a spray dryer.

The primary gas stream passes from the main cyclone to the quench tower, meets a high velocity spray of brine solution and is quenched to about 80°C. The gas then passes through a venturi scrubber. Acid gases are neutralized in the scrubber by a counter-current flow of caustic solution. The scrubbed gases then pass through the system fan to a Cleanable High Efficiency Air Filtration (CHEAF) unit. The CHEAF uses a removable fiberglass media to collect very fine entrained particulate. Nozzles above the media, spray water on the filter surface, enhancing the removal efficiency of the filter media. The clean gas then passes through an induced draft fan, a final mist eliminator stage, and the discharge stack. The stack height is ~ 22.18 meter and stack diameter is ~ 0.99 meter. Table (1) showed high scrubbing efficiencies that have been demonstrated for most heavy metals that measured during the trial burn test that was conducted for the BeeA'h incinerator.

Table (1): Air Pollution Control System Removal Efficiency for Detected Metals in Feed.

METAL	OVERALL AVERAGE
Arsenic	92.9%
Barium	99.5%
Cadmium	86.2%
Chromium (total) [a]	99.2%
Chromium (hexavalent)	99.7%
Lead	78.3%
Mercury [a]	34.3%

[a] Metal spiking at 357.2 g/hr from mercury and 131.2 g/hr for chromium.

For water liquid from air pollution control system, the spry dryer serves several functions. First, it provides the mechanism to maintain the system water balance at zero discharge. Second, the salts discharged keep the salt concentrations in equilibrium. Finally, the salt discharges carries with it heavy metals removed from the waste that must be purged from the system. The gas stream (from the flue gases, which was directed to a spray dryer) meets a co-current spray of brine solution. This solution flash dries and precipitates salts, which are separated in a second cyclone, and discharged to tote bags. The cooled and cleaned gas rejoins the main gas stream just above the quench tower.

Most of the water liquids are discharged as a steam from the discharge stack. And when liquid accumulated during start-up/shut-down conditions, which remained inside the incinerator, it is discharged to a concrete evaporation pond located in the BeeA'h facility. The bottom solids of the evaporation pond are collected and then disposed in the BeeA'h secured landfill.

The incinerator residue disposal is that, all solid residue are collected from the kiln, cyclone, and spray dryer are analyzed, stabilized if necessary and then disposed in the BeeA'h secured landfill.

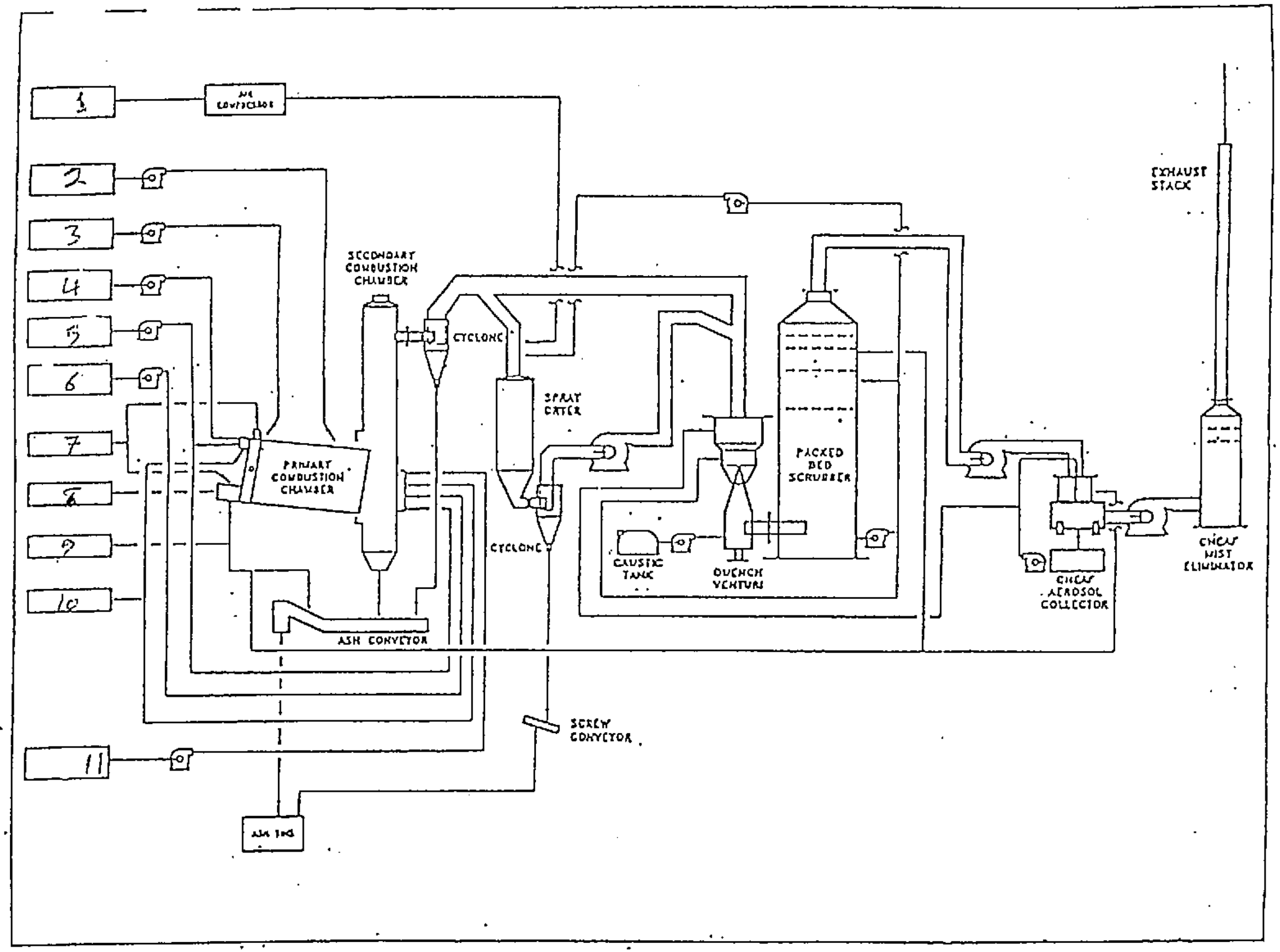


Figure (2): Schematic Diagram of the Incineration System.

Notes: 1: Ambient Air, 2: Ambient Air, 3: Ambient Air, 4: Ambient Air, 5: Liquid waste Feed, 6: Auxuliary Fuel, 7: Sludg Feed, 8: Solid Feed, 9: Water, 10: LP Gas, 11: Ambient Air.

3.2 AIR ANALYSIS METHODS

The types and quantities of air pollutants emitted from the incinerator were identified. Data were collected from BeeA'h Co. Findings were compared to air quality standards, and emission standards.

The stack is equipped with an extensive Continuous Emission Monitoring (CEM) system. Stack gases are analyzed for Carbon Monoxide (CO), Carbon Dioxide (CO2), Oxides of Nitrogen (NOx), Sulfur Dioxide (SO2). Total Hydrocarbons (THC), Oxygen (O2), and Stack gas temperature and discharge flow rate is also measured. A continuous opacity monitor has also been installed. A summary of the calibration tests and procedures of the CEM system are shown in table (2).

An extractive type, Continuous Emission Monitoring (CEM) system is operated for compliance monitoring purposes. Flue gases are drawn from the stack through a Teflon lined sampling tube. The tube is continuously heated to prevent condensate formation. The stack sample is dried, then distributed among the various continuous gas analyzers. These include Carbon Monoxide (CO), Carbon Dioxide (CO2), Oxides of Nitrogen (NOx), Sulfur Dioxide (SO2), Total Hydrocarbons (THC), and Oxygen (O2). Combustion efficiency is computed on-line. A through-the-stack continuous opacity monitor has also been installed. The type and operating range for each of the instruments are shown in table (3).

Table (2): Summary of CEM Calibration Tests and Procedures.

CALIBRATION TEST	DESCRIPTION	FREQUENCY
Performance Specification Test.	Consists of test for calibration drift, calibration error, relative accuracy, and response time as described below.	Soon after initial startup and annually thereafter.
Drift Test.	Demonstrates (precision) of monitor response with time. The difference between monitor response and two calibration standard gases (zero and span) are determined at 24-hour intervals for 7 consecutive days. CO acceptance criteria: $\leq$ 5% of span. CO_2 acceptance criteria: $\leq$ 0.5%. O_2 acceptance criteria: $\leq$ 0.5%. THC acceptance criteria: $\leq$ 3% of span. NOx acceptance criteria: $\leq$2.5% of span. SO_2 acceptance criteria: $\leq$ 2.5% of span. Opacity acceptance criteria: $\leq$ 3.0% of span.	During annual performance specification test.
Relative Accuracy Test.	Provides independent verification of CEM ability of provide accurate data and validates calibration technique. The process CEM responses are measured and compared with responses from an independent CEM using and EPA reference	During annual performance specification test.

Table (2): Summary of CEM Calibration Tests and Procedures (continued).

CALIBRATION TEST	DESCRIPTION	FREQUENCY
	method for the determination. At least 9 concurrent measurements are made. CO acceptance criteria: The mean value of the response must be ≤ 10% of the reference method mean value or 5 ppm whichever is greater. CO_2 and O_2 acceptance criteria: The mean value of the CME-response must be ≤ 20% of the reference method mean value or 1% CO_2 or O_2, whichever is greater. NOx & SO_2 acceptance criteria: The mean value of the CEM-response must be ≤20% of the mean value of the RM test data or 10% of the standard.	
Calibration Error Test.	Verifies the linearity of the CEM by determining the difference between the gas concentration indicated by the CEM and the known concentration of calibration gas at two audit points.	During annual performance specification test.

Table (2): Summary of CEM Calibration Tests and Procedures (continued).

CALIBRATION TEST	DESCRIPTION	FREQUENCY
	THC acceptance criteria: The calibration error must be $\leq$ 5% of the calibration gas value.	
Response Time Test.	Measures the time interval required for CEMS to respond to a change in combustion gas concentrations. Acceptance criteria: The response time for the CO monitor shall not exceed 1.5 minutes to achieve 95 percent of final stable value. The response time for the THC monitor shall not exceed 2 minutes to achieve 95 percent of final stable value. The response time for opacity shall be $\leq$ 10 seconds to record 95% of a step change in opacity.	During annual performance specification test. After sampling system repair or major component replacement.
Daily Calibration Check.	Test for calibration drift used to document that monitor response remains in calibration or that monitor response needs to be adjusted to the standard gas values. Acceptance criteria: Same as calibration drift.	Daily.

Table (2): Summary of CEM Calibration Tests and Procedures (continued).

CALIBRATION TEST	DESCRIPTION	FREQUENCY
Quarterly System Audit.	Conduct a Relative Accuracy Test Audit (RATA) or a Cylinder Gas Audit (CGA). This demonstrates the accuracy and linearity of monitor response. The RATA must be conducted at least once every 4 quarters using the procedure described above. The CGA is conducted in 3 or 4 quarters, but in no more than 3 quarters in succession. The CGA is performed by challenging the monitor 3 times at 2 audit points. The accuracy is then determined using the average of these 3 readings. RATA acceptance criteria: ± 15% of the average audit value or 5 ppm, whichever is greater.	Quarterly.

Table (3): Type & Operating Range for Each Analyzer

ANALYZER	TYPE	RANGE
CO_2	Non-dispersive infrared	0-25%
SO_2	Non-dispersive infrared	0-200 PPM
CO	Non-dispersive infrared	0-200 PPM
THC	Hydrogen Flame Ionization	0-100 PPM
NOx	Chemiluminescence	0-200 PPM
O_2	Magnetic pressure	0-25%
Opacity	Photometer	0-100%

mg/dscm = ppm × molecular weight of gas/22.4

The Continuos Emission Monitor–Horiba which are used has the serial no.: 502136, Horiba Fwo No. : 0459-1, Horiba Manual No. : 092479, Date: 06Th September 1995, Horiba Instruments Inc. Elam Engineering Sales. Co., Acworth, Georgia-30101, U.S.A.

3.3 WASTES ANALYSIS METHODS

The source, type and quantity of the waste were determined from records that BeeA'h Company has. The types of waste fed and residues/ash that resulted after incineration were analyzed through BeeA'h laboratory. This is to compare the residues/ash analysis results with the applicable standards. Sampling and analysis methods and procedures in table (4) were witnessed.

In the following, we will present the methodologies of waste sampling analysis. Samples of the waste feeds are collected & analyzed on a routine basis for different parameters which are Ash, Phosphorous, Sodium, Sulfur, Halogens, Bromine, Chlorine, Fluorine, Iodine, PCB, and

Heavy Metals. In addition, samples of the residue/ash are collected during the disposal & analyzed for different parameters which are pH, Conductivity, Loss on Ignition, Aluminum, Calcium, Copper, Iron, Magnesium, Potassium, Sodium, Sulfate, Sulfur, TOC, Chlorine, Antimony, Arsenic, Cadmium, Chromium Total, Lead, Mercury, and Zinc.

Table (4): Summary of Analytical Procedures and Methods.

SAMPLE NAME	ANALYSIS	PREPARATION METHOD	ANALYTICAL METHOD
Waste Feeds and Diesel Fuel.	Heating value.	Bomb Combustion.	Adiabatic Calorimeter (ASTM D240 & ASTM D2015).
	Moisture.	Gravimetric.	Drying at 105 C (ASTM D3173) Karl Fisher Titration (ASTM D1744).
	Ash content.	N/A.	Ignition (ASTM D482 & ASTM D3174).
	Chloride content.	Combustion/absorption (SW 846-5050).	Ion Chromatography or Titrimetric (SW 846-9056 & SW 846-9253), Gravimetric (ASTM D512).
	Density.	N/A.	Gravimetric/Volumetric (ASTM D1298).
	Volatile organics.	Headspace/purge and trap, or direct injection.	GC/MS & GC (SW 846-3810 & SW 846-8260).
	Polychlorinated Biphenyls (PCBs).	Solvent extraction (SW 846-3500 series).	GC/MS & GC-ECD (SW 846-8082 & SW 846-8270).
	Sodium hydroxide.	Titrimetric.	(ASTM D1067).
	Metals (Sb, As, Ba, Be, Cd, total Cr, Pb, Hg, Ag, TI).	Acid digestion (SW 846-3015).	(SW 846-7000 series), and CVAAS (SW 846-7470) as needed.

Table (4): Summary of Analytical Procedures and Methods (continued).

SAMPLE NAME	ANALYSIS	PREPARATION METHOD	ANALYTICAL METHOD
Ash/residues.	PCB.	Solvent extraction (SW 846-3500 series).	GC/MS & GC 8082 (SW 846-8270).
Caustic.	Sodium hydroxide.	N/A.	Titration.
	Metals (Sb, As, Ba, Be, Cd, total Cr, Pb, Hg, Ag, Tl).	Acid digestion (SW 846-3015).	ICP (SW 846-6010), GFAAS (SW 846-7000 series), and CVAAS (SW 846-7470) as needed.
Stack gas M0010.	Semi volatile POHC and other SVOCs.	Solvent extraction (SW 846-3500 series).	HRGC/HRMS (SW 846-8270).
	PCBs	Solvent extraction (SW 846-3500 series).	HRGC/HRMS (EPA Method 680).
Stack gas M0010.	PCDD/PCDF.	Solvent extraction (SW 846-3500 series).	HRGC/HRMS (EPA Method 23, SW 846-8290).
Stack gas M0030.	Volatile POHC and other VOCs.	Thermal desorption trap (SW-846-5041).	GC/ MS (SW 846-5041).
Stack gas M0061.	Hexavalent chromium.	N/A.	Ion chromatography, post-column reactor (SW 846-7199).

Table (4): Summary of Analytical Procedures and Methods (continued).

SAMPLE NAME	ANALYSIS	PREPARATION METHOD	ANALYTICAL METHOD
Stack gas M0050.	Particulate.	Evaporation/desiccate.	Gravimetric (EPA Method 5).
	HCl/HF/CL2.	N/A.	Ion chromatography (Method 9057, BIF Guidance; EPA 300.0).
	Moisture.	N/A.	Gravimetric (EPA Method 4).
	Oxygen, carbon dioxide.	N/A.	CEM (EPA Method 3A).
	Temperature.	N/A.	Thermocouple (EPA Method 2).
	Flow rate.	N/A.	Pitot tube (EPA Method 2).

Notes:
"ASTM" refers to American Society for Testing and Materials, Annual Book for ASTM Standards.
"EPA Method" refers to New Source Performance Standards, Test Methods and Procedures, Appendix A, 40 CFR 60.
"SW 846" refers to Methods for Evaluating Solid Waste, Third Edition, November 1996, and Updates.
(M) = Modified. Specific modifications will be applied to the QA/QC criteria of SW 846 Method 8240 to make it consistent with SW- 486 Method 5041.
SPCC excluding those that boil below 30^0C and those that boil above 132^0C, will be greater than 0.3 in accordance with SW-846 Method 5041.
N/A: Not Applicable.

The samples collection methodology for waste feed & residue/ash are as follwos (USEPA 1982).

Documentation of Chain of Custody: An essential part of any sampling/analytical scheme is ensuring the integrity of the sample from collection to data reporting. This includes the ability to trace the possession and handling of samples from the time of collection through analysis and final disposition. This documentation of the history of the sample is refereed to as chain of Custody.

Chain of custody is necessary if there is any possibility that the analytical data or conclusions based upon analytical data will be used in litigation. In cases where litigation is not involved, many of the chain-of-custody procedures are still useful for routine control of sample flow. The components of chain of custody - sample seals, a field log book, chain-of-custody record, and sample analysis request sheet - and the procedures for their use are described in the following sections.

Sample Labels: Sample labels are necessary to prevent misidentification of samples. Gummed paper labels or tags are adequate and should include at least the following information:

- Sample number.
- Name of collector.
- Date and time of collection.
- Place of collection.

Labels should be affixed to sample containers prior to or at the time of sampling. The labels should be filled out at the time of collection.

Sample Seals: Sample seals are used to detect tampering of samples following sample collection up to the time of analysis. Gummed paper seals may be used for this purpose. The paper seal should include, at least, the following information:

- Sample number (This number must be identical with the number on the sample label).
- Collector's name.
- Date and time of sampling.

The seal must be attached in such a way that it is necessary to break it in order to open the sample container. Seals must be affixed to containers before the samples leave.

Field Log Book: All information pertinent to a field survey sampling must be recorded in a logbook. This should be bound, preferably with consecutively numbered pages that are 21.6 by 27.9 cm (8.5 by 11 in.) Sampling situations vary widely. No general rule can be given as to the extent of information that must be entered in the logbook. A good rule, however, is to record sufficient information so that someone can reconstruct the sampling without reliance on the collector's memory. The log must be protected and kept in a safe place.

Chain-or-Custody Record: To establish the documentation necessary to trace sample possession from the time of collection, a chain-of-custody record should be filled out on accompany every sample. This record becomes especially important if the sample is to be introduced as evidence in a court litigation. The record should contain the following minimum information.

- Sample number.
- Signature of collector.
- Date and time of collection.
- Place and address of collection.
- Waste type.
- Signature of persons involved in the chain of possession.
- Inclusive dates of possession.

Sample Analysis Request Sheet: The sample analysis request sheet is intended to accompany the sample on delivery to the laboratory. The field portion of this form is completed by the person collecting the sample and should include most of the pertinent information noted in the logbook. The laboratory portion of this form is intended to be completed by laboratory personnel and to include at a minimum :

- Name of person receiving the sample.
- Laboratory sample number.
- Date of sample receipt.
- Sample allocation.

- Analyses to be performed.

Sample Delivery to the Laboratory: The sample should be delivered to the laboratory for analysis as soon as practicable- usually within 1 or 2 days after sampling. The sample must be accompanied by the chain-of-custody record and by a sample request sheet. The sample must be delivered to the person in the laboratory authorized to receive samples (often referred to as the sample custodian).

Receipt and logging of Sample: In the laboratory, a sample custodian should be assigned to receive the samples. Upon receipt of a sample, the custodian should inspect the condition of the sample and the sample seal, reconcile the information on the sample label and seal against the on the chain-of-custody record, assign a laboratory number, log in the sample in the laboratory log book, and store the sample in a secured sample storage room or cabinet unit assigned to an analyst for analysis.

The sample custodian should inspect the sample for any leakage from the container. A leaky container containing multiphase sample should not be accepted for analysis. This sample will no longer be a representative sample. If the sample is contained in a plastic bottle and the container walls show that the sample is under pressure or releasing gases, the sample should be treated with caution since it may be explosive or release extremely poisonous gases. The custodian should examine whether the sample seal is

intact or broken, since a broken seal may mean sample tampering and would make analysis results inadmissible in court as evidence. Any discrepancies between the information on the sample label and seal and the information that is on the chain-of-custody record and the sample analysis request sheet should be resolved before the sample is assigned for analysis. This effort might require communication with the sample collector. Results of the inspection should be noted on the sample analysis request sheet and on the laboratory sample logbook.

Incoming samples usually carry the inspector's or collector's identification numbers. To further identify these samples, the laboratory should assign its won identification numbers, which normally are given consecutively. Each sample should be marked with the assigned laboratory number. This number is correspondingly recorded on a laboratory sample logbook along with the information describing the sample. The sample information is copied from the sample analysis request sheet and crosschecked against that on the sample label.

Assignment of Sample for Analysis: In most cases, the laboratory supervisor assignees the sample for analysis. The supervisor should review the information on the sample analysis request sheet, which now includes inspection notes recorded by the laboratory sample custodian. The technician assigned to analysis should record in the laboratory notebook the identifying information about the sample, the date receipt, and other pertinent information. This record should also include the subsequent testing date and calculations. The

sample may have to be split with other laboratories in order to obtain all the necessary analytical information. In this case, the same type of chain-of-custody procedures must be employed at the other laboratory and while the sample is being transported to the other laboratory.

Once the sample has been received in the laboratory, the supervisor or his assignee is responsible for its care and custody. He should be prepared to testify that the sample was in his possession or secured in the laboratory at all times from the moment it was received from the custodian until the analyses were performed.

Sampling Methodology: The sampling methodology will be determined in part by the sampling strategy to be employed. There are four different types of sampling strategies (simple random, stratified random, systematic random, and authoritative sampling). The latter three strategies require more information than the simple random approach. This additional information must either be acquired through sampling or must be estimated. The information requirements of the sampling strategy to be used should be kept in mind when designing a sampling plan.

The methods and equipment used for sampling waste materials will vary with the form and consistency of the waste materials to be sampled. For extremely viscous liquid, ASTM Standard D140-70 will be used. For crushed or powdered material,

ASTM Standard D346-75 will be used. For soil or rock-like material, ASTM Standard D420-69 will be used. For Soil-like material, ASTM Standard D1452-65 will be used. For fly-ash-like material, ASTM Standard D2234-76 will be used.

In the following, we will discuss the analysis procedures for each parameter that to be analyzed for both waste feed & residue/ash.

3.3.1 BOMB PREPARATION METHOD FOR SOLID WASTE DETERMINATION OF HALOGENS

Summary of Method:

The sample is oxidized by combustion in a bomb containing oxygen under pressure. The liberated halogen compounds are absorbed in a sodium carbonate/sodium bicarbonate solution Samples with a high water content (>25%) may not combust efficiently and may require the addition of mineral oil to facilitate combustion. The bomb combustion solution can then be analyzed for halogen contents gravimetrically by precipitation. The individual anion species can also be determined by one or more of the following methods:

- Chloride Titrimetric, Mercuric Nitrate, Method # 9252 SW-846 will be used.
- Chloride Titrimetric, Silver Nitrate, Method # 9253 SW-846 will be used.

- Chloride Gravimetric, Precipitation, Method # D808-95 ASTM will be used.
- Inorganic Anions,by Ion Chromatography.

For more details of the sample preparations, reagents, procedures and calculations, please refer to the reference page (BeeA'h Environmental Laboratory, Standards Operating Procedures).

3.3.2 ACID DIGESTION OF SEDIMENTS, SLUDGE, AND SOILS

Summary of Method:

This method is an acid digestion procedure used to prepare sediments, sludge, and soil samples for analysis by flame or furnace Atomic Absorption (AA) spectroscopy (group1 and group2, respectively) or by Inductively Coupled argon Plasma (ICP) spectroscopy. Samples prepared by this method may be analyzed by ICP for all the listed metals.

A representative 1 to 2 g (wet weight) sample is digested in nitric acid and hydrogen peroxide. The digestive is then refluxed with either nitric acid or hydrochloric acid. Hydrochloric acid is used for flame Atomic Absorption (AA) and ICP analyze and nitric acid is used for furnace AA work. Dilute hydrochloric acid is used as the final reflux acid for (1) the ICP analysis of As and Se, and (2) the flame AA or ICP analysis of Ag, Al, Ba, Be, Ca, Cd, Co,

Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Os, Pb, Tl, V, and Zn. Dilute nitric acid is employed as the final dilution acid for the furnace AA analysis of As, Be, Cd, Cr, Co, Fe, Pb, Mo, Se, T1, and V. The diluted samples have an approximate acid concentration of 5.0% (v/v). A separate sample shall be dried for a total % solids determination.

For more details of the sample preparations, reagents, procedures and calculations, please refer to the reference page (USEPA 1992).

3.3.3 DETERMINATION OF INORGANIC ANIONS BY ION CHROMATOGRAPHY

Summary of Method:

- This method address the sequential determination of the anions chloride, fluoride, bromide, nitrate, nitrite, phosphate, and sulfate in the collection solutions from the bomb combustion of solid waste samples, as well as all water samples.
- The Method Detection Limit (MDL), the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is above zero, varies for anions as a function of sample size and the conductivity scale used. Generally, minimum detectable concentrations are in the range of 0.05 mg/L for F and 0.1 mg/L for Br, Cl, NO_3, NO_2, PO_4, and SO_4, with 100 -µL sample loop and a 10 µmho

full-scale setting on the conductivity detector. Similar values may be achieved by using a higher scale setting and an electronic integrator. Idealized detection limits of an order of magnitude lower have been determined in reagent water by using a 1-μmho/cm full-scale setting. The upper limit of the method is dependent on total anion concentration and may be determined experimentally. These limits may be extended by appropriate dilution.

- A small volume of combustion collection solution or other water sample, typically 2 to 3 ml, is injected into an ion chromatography to flush and fill a constant volume sample loop. The sample is then injected into a stream of carbonate-bicarbonate effluent of the same strength as the collection solution or water sample.
- The sample is pumped through three different ion exchange columns and into a conductivity detector. The first two columns, a pre-column or guard column and a separator column, are packed with low-capacity, strongly basic anion exchanger , Ions are separated into discrete bands based on their affinity for the exchange sites of the resin. The last column is a suppresser column that reduces the background conductivity of the effluent to a low or negligible level and converts the anions in the sample to their corresponding acids. The separated anions in their acid form are measured using an electrical-conductivity cell. Anions are identified based on their

retention times compared to known standards. Quotation is accomplished by measuring the peak height or area and comparing it to a calibration curve generated from known standards.

For more details of the sample preparations, reagents, procedures and calculations, please refer to the reference page (USEPA 1994).

3.3.4 STANDARD TEST METHOD FOR CHLORINE IN NEW AND USED PETROLEUM PRODUCTS (BOMB METHOD)

Summary of Method:

- This test method covers the determination of chlorine in lubricating oils and greases, including new and used lubricating oils and greases containing additives, and in active concentrates. Its range of applicability is 0.1 to 50% chlorine. The procedure assumes that compounds containing halogens other than chlorine will not be present.
- The preferred units are mass percent and SI.
- The sample is oxidized by combustion in a bomb containing oxygen under pressure. The chlorine compounds thus liberated are absorbed in a sodium carbonate solution and the amount of chlorine present is determined gravimetrically by perception as silver chloride.

For more details of the sample preparations, reagents, procedures and calculations, please refer to the reference page (ASTM 1995).

3.3.5 ORGANIC CARBON (TOTAL) METHOD

Summary of Method:

The organic carbon in water and wastewater is composed of a variety of organic compounds in various oxidation states. To determine the quantity of organically bound carbon, the organic molecules must be broken down to single carbon units and converted to a single molecular form that can be measured quantitatively. Total Organic Carbon (TOC) methods utilize heat and oxygen, ultraviolet irradiation, chemical oxidants, or combinations of these oxidants to convert organic carbon to Carbon Dioxide (CO_2). The CO_2 may be measured directly by a non dispersive infrared analyzer, it may be reduced to methane and measured with a flame ionization director, or CO_2 may be titrated chemically.

For more details of the sample preparations, reagents, procedures and calculations, please refer to the reference page (ASTM 1985).

3.3.6 COMBUSTION - INFRARED METHOD

Summary of Method:

The combustion-infrared method has been used for a wide variety of samples, but its accuracy is dependent on particle size reduction because it uses small-orifice syringes. The principle of this is the sample is homogenized and diluted as necessary and a microportion is injected into a heated reaction chamber packed with an oxidative catalyst such as cobalt oxide. The water is vaporized and the organic carbon is oxidized to CO_2 and H_2O. The CO_2 from oxidation of organic and Inorganic Carbon (IC) is transported in the carrier-gas streams and is measured by means of a nondispersive infrared analyzer. Because Total Carbon is measured, IC must be measured separately and Total Organic Carbon (TOC) obtained by difference.

For more details of the sample preparations, reagents, procedures and calculations, please refer to the reference page (ASTM 1985).

3.3.7 TOXICITY CHARACTERISTIC LEACHING PROCEDURE (TCLP) METHOD

Summary of Method:

In order to predict if a particular waste is likely to leach chemicals into ground water at dangerous levels; EPA designed a lab procedure to replicate the leaching process and other conditions that occur when wastes are buried in a typical municipal landfill.

This lab procedure is known as the Toxicity Characteristic Leaching Procedure (TCLP).

The regulations require a facility to apply the TCLP to its hazardous waste samples in order to create a liquid leachate. This leachate would be similar to the leachate generated by a landfill containing a mixture of household and industrial wastes. Once this leachate is created via the TCLP, the waste handler must determine whether it contains any of different chemicals in the specified regulatory levels. These regulatory levels are based on groundwater modeling studies and toxicity data that calculate the limit above which these common toxic compounds and elements will threaten human health and the environment. If the leachate sample contains a concentration above the regulatory limit for one of the specified chemicals, the waste exhibits the toxicity characteristics and carries the waste code associated with that compounds or element (USEPA RCRA Manual). In addition, the TCLP is designed to determine the mobility of both organic and inorganic compounds present in liquid, solid, and multiphase wastes.

For more details of the sample preparations, reagents, procedures and calculations, please refer to the reference page (USEPA 1992).

3.4 SPECIAL WASTES SAMPLE ANALYSIS

A special sample from the subject incinerator was collected on 22 December 1999 for a one-time analysis. One sludge sample from the waste feed before incineration, and one solid sample of the ash material after incineration were collected in order to, analyze for selective chemical and physical analysis parameters (table no 18). This is to compare the results with the other analysis results of waste feed and residues/ash waste that obtained from BeeA'h Company. The selective chemical and physical analysis parameters were pH, Conductivity, Ash, Loss on Ignition, Moisture Content, Calcium, Chloride, Iron, Magnesium, Potassium, Silica, Sodium, Sulfur, Arsenic, Cadmium Chromium Total, Lead, Mercury, and Zinc. The above analysis parameters were analyzed and conducted in Al-Hoty-Stanger Co. Laboratory in Al-Khobar, Kingdom of Saudi Arabia. The analysis were carried out by using the test procedures as outlined below:

- Vogel's Quantitative Inorganic Analysis, 4th edition, published by Longman Group Ltd., London, U.K.
- Furman, N. H., Standard Methods of Chemical Analysis, 6th edition, published by Robert E. Krieger Publishing Co., Florida, U.S.A.
- EPA Test Methods for Evaluating Solid Waste, Vol. 1A, Third Edition (1986), U.S. Department of Commerce, National Technical Information services, Springfield, VA 22161, USA.

An incinerator system can be analyzed on a gross basis, as can any other self-contained physical or chemical system. In the

discussion section, material balance technique will be conducted that will provide an analysis of system inputs and outputs. The purpose of material balance calculations is to determine quantity inputs and outputs of a system. Material balance calculations are applications of the first law of thermodynamics; in a steady state the inputs to a system are equal to the outputs from that system. In addition, it is to insure and evaluate the accuracy of the analysis and what remain in the system. The special sample that was collected on 22 December 1999 from BeeA'h incinerator for a one-time analysis will be used to conduct the material balance analysis.

Furthermore, and by its definition, a waste stream cannot be completely defined. The basic analysis of the stream may be known, but most wastes change in both characteristics and quantity from day to day and from hour to hour. Detailed calculations describing wastes and thermal processes are, at best, approximations. Minor losses in accuracy within assumptions made to expedite calculations are insignificant when compared to the inaccuracies caused by constant changes in the nature of the waste stream (Brunner 1989).

4. RESULTS

The quantities of waste fed were identified at the mentioned private sector company (National Environmental Preservation Co. BeeA'h). Information on waste types was gathered and presented in table (5) and figure (3).

The types of waste fed were identified from BeeA'h Co. records. In addition, the laboratory monthly average data analysis were identified from BeeA'h log sheets that recorded for each month for selective days for analysis.

The source of samples is from mixture of waste from different sources such as; oily sludge, grease, coke, evaporation pond residues, hydrocarbon emulsion, caustic sludge, tank bottom sludge,...etc. The waste types are fed to the hazardous waste incineration system through three waste feed systems:

- Liquid waste feed system.
- Solid waste feed system.
- Sludge waste feed system.

Each of these feed systems has been designed to handle material in a wide range of physical and chemical properties. The combination of the three systems allows material of virtually any form except gasses to be handled and fed the hazardous waste incineration.

The monthly average data are presented in tables (6), (7) & (8) and figures 4-36. In tables (6) & (8) there were no data available (not measured) from BeeA'h company for the month of November 1997.

The types of residues solids/ash, that resulted after incineration were analyzed in BeeA'h Company laboratory. The monthly average data are presented in table (9) and figures 37-40. There were no data available (not measured) from BeeA'h company for the months of November, 1997, Decemeber 1997, Janaury 1998, February 1998, April 1998, and May 1998.

The monthly average results (October 1997-June 1998) of the ash solids after incineration were compared to the Toxicity Characteristic Leaching Procedure (TCLP) regulatory levels and are presented in table (11).

The monthly average data results of 9 months (October 1997-June 1998) of incineration waste feed were compared to the monthly average data results of 9 months (October 1997-June 1998) ash solids after incineration are presented in table (12).

The monthly average data of air pollutants emitted from the incinerator that analyzed at BeeA'h are presented in tables (13) & (14) and figures 41-54. In tables (13) & (14) there were no data available (not measured) from BeeA'h company for the months of October and November 1997.

The monthly average data results of 9 months (October 1997-June 1998) were compared to air pollution source standards and are presented in table (17).

The chemical and physical analysis parameters of the special sample from the subject incinerator are presented in table (18).

The monthly average data results of 9 months (October 1997-June 1998) of incineration waste feed were compared to the special sample that of collected on 22 December 1999 of incineration feed and are presented in table (19).

The monthly average data results of 9 months (October 1997-June 1998) of ash solids after incineration were compared to the special sample that of collected on 22 December 1999 of ash after incineration and are presented in table (20).

Table (5): Incineration Waste Quantities.

QUANTITIES	OCT., 1997	NOV., 1997	DEC., 1997	JAN., 1998	FEB., 1998	MAR., 1998	APR., 1998	MAY, 1998	JUN., 1998
Total Waste (kg)	298,547.00	275,686.00	310,673.00	531,085.00	348,260.00	386,494.00	297,460.00	331,360.00	524,512.00
% Distribution of Waste as Solids	37.6	19.9	8.1	58.4	86.2	69.3	38.9	48.8	90.4
% Distribution of Waste as Sludge	49.9	65.4	87.2	35.1	8.0	20.9	50.5	46.2	5.2
% Distribution of Waste as Hazardous Liquid	12.5	14.7	4.7	6.5	5.8	9.8	10.6	5.0	4.4

Table (6): Incineration Feed Analysis (Solids).

PARAMETERS	OCT., 1997	DEC., 1997	JAN., 1998	FEB., 1998	MAR., 1998	APR., 1998	MAY, 1998	JUN., 1998
Ash (wt%)	65.57	27.00	31.45	59.80	80.43	59.10	83.10	85.60
Phosphorous (mg/kg)	1.00	0.60	18.10	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available
Sodium (mg/kg)	22840.60	0.60	72.81	805.33	1516.00	No Data Available	1935.40	479.50
Sulfur (mg/kg)	23940.60	15880.20	21550.62	15259.00	75643.29	42100.00	56517.10	17497.50
Halogens (mg/kg)	21203.00	8482.00	13772.81	5076.00	8426.57	9260.00	6561.40	12597.80
Bromine (mg/kg)	1.00	0.60	7.95	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available
Chlorine (mg/kg)	21200.00	8480.20	13750.86	5076.00	8426.57	9260.00	6561.40	12597.80
Fluorine (mg/kg)	1.00	0.60	13.38	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available
Iodine (mg/kg)	1.00	0.60	0.57	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available
PCB (mg/kg)	1.00	0.60	29.33	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available
Heavy Metals (mg/kg)	1.00	0.60	652.86	755.56	2045.29	2310.00	254.30	726.60

Note:
As per BeeA'h log sheets recorded for each month for selective days for analysis (average of these log sheets of selective days).
No data were available on the month of November, 1997.

Table (7): Incineration Feed Analysis (Sludge).

PARAMETERS	OCT., 1997	NOV., 1997	DEC., 1997	JAN., 1998	FEB., 1998	MAR., 1998	APR., 1998	MAY, 1998	JUN., 1998
Ash (wt%)	10.29	25.00	5.00	8.57	9.22	3.29	11.90	12.53	7.31
Phosphorous (mg/kg)	1.00	1.00	1.00	0.48	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available
Sodium (mg/kg)	16315.0	1.00	19100.00	5422.71	18.44	No Data Available	No Data Available	4914.30	8194.36
Sulfur (mg/kg)	13985.71	59400.00	1000.00	16871.00	13014.89	1757.14	1479.80	4442.90	12982.86
Halogens (mg/kg)	2074.43	5023.00	3103.00	8151.71	883.11	342.86	860.00	978.60	4998.57
Bromine (mg/kg)	1.00	1.00	1.00	0.48	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available
Chlorine (mg/kg)	2071.43	5020.00	3100.00	8150.29	883.11	342.86	860.00	978.60	4998.57
Fluorine (mg/kg)	1.00	1.00	1.00	0.48	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available
Iodine (mg/kg)	1.00	1.00	1.00	0.48	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available
PCB (mg/kg)	1.00	1.00	1.00	0.48	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available
Heavy Metals (mg/kg)	129.14	140.20	1.00	6.05	5.78	0.71	No Data Available	0.43	0.43

Note:
As per BeeA'h log sheets recorded for each month for selective days for analysis (average of these log sheets of selective days).

Table (8): Incineration Feed Analysis (Hazardous Liquid).

PARAMETERS	OCT., 1997	DEC., 1997	JAN., 1998	FEB., 1998	MAR., 1998	APR., 1998	MAY, 1998	JUN., 1998
Ash (wt%)	0.71	0.06	0.17	0.33	0.03	0.03	0.09	0.10
Phosphorous(mg/kg)	0.71	0.60	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available
Sodium (mg/kg)	0.71	150.00	No Data Available	No Data Available	No Data Available	No Data Available	107.14	101.56
Sulfur (mg/kg)	788.86	4110.00	293.86	13399.33	35714.29	24684.25	84600.00	43443.75
Halogens (mg/kg)	218573.85	344401.80	9038.43	54209.67	168857.14	149877.50	514285.71	608375.00
Bromine (mg/kg)	0.71	0.60	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available
Chlorine (mg/kg)	218571.71	344400.00	9038.43	54209.67	168857.14	149877.50	514285.71	608375.00
Fluorine (mg/kg)	0.71	0.60	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available
Iodine (mg/kg)	0.71	0.60	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available	No Data Available
PCB (mg/kg)	0.71	0.60	14285.71	17777.78	No Data Available	No Data Available	No Data Available	66875.00
Heavy Metals (mg/kg)	2.43	3.00	No Data Available	No Data Available	1.43	1.25	4.29	5.00

Note:
As per BeeA'h log sheets recorded for each month for selective days for analysis (average of these log sheets of selective days).
No data were available on the month of November, 1997.

Table (9): Ash Solids Analysis.

PARAMETERS	OCT., 1997	MAR., 1998	JUN., 1998
Loss on Ignition (wt%)	<0.20	2.37	28.50
Calcium (mg/kg)	No Data Available	151250.00	No Data Available
Sodium (mg/kg)	No Data Available	12500.00	No Data Available
Sulfur (mg/kg)	No Data Available	5333.00	No Data Available
TOC (mg/kg)	<0.10	No Data Available	No Data Available
Chlorine (mg/kg)	No Data Available	6636.00	No Data Available
Arsenic (mg/kg)	<0.01	No Data Available	No Data Available
Cadmium (mg/kg)	0.05	9.50	0.03
Chromium Total (mg/kg)	<0.003	85.50	53.19
Lead (mg/kg)	<0.03	108.52	0.22
Mercury (mg/kg)	<0.01	No Data Available	No Data Available

Note:
All Arsenic, Cadmium, Chromium Total, Lead, and Mercury parameters were analyzed by the Toxicity Characteristic Leaching Procedure (TCLP) method.
No data were available on the months of November, 1997, Decemeber 1997, Janaury 1998, February 1998, April 1998, & May 1998.

Table (10): Some of Toxicity Characteristic Leaching Procedure (TCLP) regulatory levels. Source: RCRA Subtitle C, Managing Hazardous Waste, US EPA.

CONTAMINANT	CONCENTRATION (PPM)
Arsenic	5.00
Cadmium	1.00
Chromium	5.00
Lead	5.00
Mercury	0.20

Table (11): Comparison of Monthly Average Results (October 1997-June 1998) between Ash Solids and Some of Toxicity Characteristic Leaching Procedure (TCLP) regulatory levels.

CONTAMINANT	OCT., 1997	MAR., 1998	JUN., 1998	TCLP CONC. (PPM)
Arsenic (PPM)	<0.01	No Data Available	No Data Available	5.00
Cadmium (PPM)	0.05	9.50	0.03	1.00
Chromium (PPM)	<0.003	85.50	53.19	5.00
Lead (PPM)	<0.03	108.52	0.22	5.00
Mercury (PPM)	<0.01	No Data Available	No Data Available	0.20

Table (12): Comparison of Average Results of 9 Months(October 1997-June 1998) between Incineration Waste Feed and Ash solids After Incineration.

PARAMETERS	AVERAGE RESULTS OF 9 MONTHS OF THE INCINERATION FEED (SOLIDS)	AVERAGE RESULTS OF 9 MONTHS OF THE INCINERATION FEED (SLUDGE)	AVERAGE RESULTS OF 9 MONTHS OF THE INCINERATION FEED (HAZARDOUS LIQUID)	AVERAGE RESULTS OF 9 MONTHS OF THE ASH SOLIDS AFTER INCINERATION
Ash (wt%)	61.51	10.35	0.19	No Data Available
Loss on Ignition (wt%)	No Data Available	No Data Available	No Data Available	10.36
Calcium (mg/kg)	No Data Available	No Data Available	No Data Available	151250.00
Phosphorous (mg/kg)	6.57	0.87	0.66	No Data Available
Sodium (mg/kg)	3950.03	6745.73	89.85	12500.00
Sulfur (mg/kg)	33548.54	13881.59	25879.29	5333.00
TOC (mg/kg)	No Data Available	No Data Available	No Data Available	<0.01
Halogens (mg/kg)	10672.45	2935.03	200602.38	No Data Available
Bromine (mg/kg)	3.18	0.87	0.66	No Data Available
Chlorine (mg/kg)	10669.1	2933.86	258451.88	6636.00
Fluorine (mg/kg)	4.99	0.87	0.66	No Data Available
Iodine (mg/kg)	0.72	0.87	0.66	No Data Available
PCB (mg/kg)	10.31	0.87	19787.96	No Data Available
Heavy Metals (mg/kg)	843.28	35.47	2.90	No Data Available
Arsenic (mg/kg)	No Data Available	No Data Available	No Data Available	<0.01
Cadmium (mg/kg)	No Data Available	No Data Available	No Data Available	3.19
Chromium Total (mg/kg)	No Data Available	No Data Available	No Data Available	46.23
Lead (mg/kg)	No Data Available	No Data Available	No Data Available	36.26
Mercury (mg/kg)	No Data Available	No Data Available	No Data Available	<0.01

Table (13): Stack Emissions (Gas Concentrations).

PARAMETERS	DEC., 1997	JAN., 1998	FEB., 1998	MAR., 1998	APR., 1998	MAY, 1998	JUN., 1998	AVERAGE RESULTS OF 9 MONTHS
CO (mg/dscm)	4.00	2.00	2.00	3.0	2.00	2.00	2.00	2.43
CO_2 (g/dscm)	111.00	124.00	115.00	117.00	142.00	121.00	122.00	121.71
NO_X (mg/dscm)	194.00	173.00	143.00	176.00	153.00	185.00	155.00	168.43
SO_2 (mg/dscm)	84.00	36.00	28.00	51.00	41.00	45.00	47.00	47.43
THC (mg/dscm)	2.00	1.00	4.00	3.00	1.00	2.00	2.00	2.14
O_2(%)	11.50	12.50	12.50	12.00	11.80	12.80	12.60	12.24
Stack Gas Flow Rate (acmh)	28,315.00	38,175.00	34,487.00	35,446.00	36,322.00	36,211.00	36,122.00	35,023.86

Notes:

dscm: dry standard cubic meter.

acmh: actual cubic meters/hr.

Kiln temperature typically are in the range 930°C to 960°C.

Secondary Combustion Chamber (SCC) in the range 1100°C to 1300°C. Stack gas temperature is around 80° C.

Stack Height is ~ 22.18 meter, Stack diameter is ~ 0.99 meter, mg/dscm = ppm × molecular weight of gas/24.05

No data were available on the months of October 1997 & November, 1997.

Table (14): Stack Emissions (Emissions Rate).

PARAMETERS	DEC., 1997	JAN., 1998	FEB., 1998	MAR., 1998	APR., 1998	MAY, 1998	JUN., 1998	AVERAGE RESULTS OF 9 MONTHS
CO (kg/day)	2.70	1.80	1.70	2.60	1.70	1.74	1.73	2.00
CO_2 (kg/day)	75,431	113,609	95,184	99,532	123,785	101,508	101,507	101,508
NO_X (kg/day)	131.80	158.50	118.40	149.70	133.40	160.78	134.37	140.99
SO_2 (kg/day)	57.10	33.00	23.20	43.40	35.70	39.11	40.75	37.61
THC (kg/day)	1.40	0.90	3.30	2.60	0.90	1.74	1.73	1.79
Particulates (kg/day)	20.90	28.20	25.50	26.20	26.80	25.52	25.50	25.52
Water (kg/day)	230,401.00	310,632.00	280,622.00	288,426.00	295,554.00	281,127.00	281,100.00	281,123.14

Notes:
No data were available on the months of October 1997 & November, 1997.

Table (15): Air pollution Source Standards. Source: Royal Commission Environmental Regulation, Saudi Arabia (September, 1999)

INDUSTRY	SOURCE	POLLUTANTS	EMISSION STANDARDS
Hazardous and Medical Waste Incineration	Incinerator	Particulate	34 mg/dscm corrected to 7% oxygen
		Hydrogen Chloride	100 mg/dscm OR at least 99% removal efficiency if emission is > 1.8 kg/h
		Sulfur Dioxide	500 mg/dscm
		CO	100 mg/dscm
		PCB	1 mg/kg PCB feed, for a maximum one hour average concentration (99.9999%) destruction removal efficiency-DRE)
		Total Dioxins & Furans	30 ng/dscm
		Organic	The DRE for each organic constituent of the waste, shall be at least 99.99%.
		Visible emissions	10% opacity except for no more than 6 minutes in any hour
		Hydrogen Fluoride	5 mg/dscm
		Metals	Sb-300 g/h; Pb-90 g/h
			Ag-3000 g/h; Ba-50,000 g/h
			Hg-300 g/h; Tl-300 g/h
			As-2.3 g/h; Cd-5.4 g/h
			Cr-0.82 g/h; Be-4.0 g/h
	Incinerator-secondary chamber	Temp.	1100 C minimum
	Incinerator-secondary chamber	Time	Two seconds (2S) minimum

Table (16): Ambient Air Quality Standards. Source: Royal Commission Environmental Regulation, Saudi Arabia (September, 1999)

POLLUTANTS	AVERAGING PERIOD	MAXIMUM CONCENTRATIONS[1]	
		ug/m^3	PPM
Sulfur Dioxide (SO_2)	1 hour[2]	730	0.280
	24 hour[3]	365	0.140
	Annually	80	0.030
Nitrogen /Oxides as (NO_X)	1 hour[2]	660	0.350
	Annually	100	0.050
Carbon Monoxide (CO)	1 hour[2]	40,000	35
	8 hour[2]	10,000	9
Hydrogen Sulfide (H_2S)	1 hour[3]	200	0.140
	24 hour[3]	40	0.030
Photochemical Oxidants as Ozone (O_3)	1 hour[3]	240	0.120
Inhalable Particulates[4][5] (PM10)	24 hour[3]	150	-
	Annually	50	-
Lead	3 month	1.5	-
Fluorides	Monthly	1.0	-
Sulfate	24 hour	25	-
Chlorine (Cl_2)	1 hour	300	0.1
Ammonia (NH_3)	1 hour	1800	2.6
Non-Methane Organic Carbons [6] (NMOC)	3 hour	160	0.24

Notes:

(1) Reference conditions are 25 C and 760 mm HG.
(2) Not to be exceeded more than twice per month.
(3) Not to be exceeded more than once per year.
(4) Inhalable particulate:< 10 microns equivalent aerodynamic diameter.
(5) The exceedanee of the 24 hour or annual inhalable particulate standard as a result of abnormal natural background concentrations shall not be considered a violation of the standard.
(6) There is no adopted standard for NMOC: this level is a goal to aid in the control of ambient ozone concentrations. Sampling period 0600-0900 hours.

Table (17): Comparison of Average Results of 9 Months(October 1997-June 1998) between Stack Emissions (Gas Concentrations) and Air pollution Source Standards.

POLLUTANTS	AVERAGE RESULTS OF 9 MONTHS OF STACK EMISSIONS (GAS CONCENTRATIONS)	EMISSION STANDARDS
CO (mg/dscm)	2.43 mg/dscm	100 mg/dscm
SO_2 (mg/dscm)	47.43 mg/dscm	500 mg/dscm

Table (18): Chemical and Physical Analysis for Special Sample for One-Time Analysis on December, 1999.

PARAMETERS	RESULTS OF ONE SAMPLE OF THE WASTE FEED BEFORE INCINERATION	RESULTS OF ONE SAMPLE OF THE ASH MATERIAL AFTER INCINERATION
pH	12.50	11.30
Conductivity (mS)	1150.00	8500.00
Ash (wt%) @ 550° C	31.30	98.00
Loss on Ignition (wt%) @ 950° C	4.16	2.46
Moisture Content (wt%)	21.60	0.03
Calcium (wt%)	20.90	21.50
Chloride (wt%)	2.14	0.36
Iron (wt%)	0.58	0.61
Magnesium (wt%)	0.35	1.17
Potassium (wt%)	0.05	<0.01
Silica (wt%)	6.50	3.82
Sodium (wt%)	6.03	0.30
Sulfur as SO_3 (wt%)	42.30	0.80
Arsenic (wt%)	0.0074	0.0014
Cadmium (wt%)	0.01	0.04
Chromium Total (wt%)	0.04	0.11
Lead (wt%)	0.10	0.11
Mercury (wt%)	0.0034	0.0025
Zinc (wt%)	0.19	0.03

Note:
All Calcium, Chloride, Iron, Magnesium, Potassium, Silica, Sodium, Sulfur, Arsenic, Cadmium, Chromium Total, Lead, Mercury, and Zinc parameters were analyzed after ashing the sample at 550° C.

Table (19): Comparison of Average Results of 9 Months (October 1997-June 1998) between Incineration Waste Feed and Special Sample collected On December, 1999 of Incineration Feed.

PARAMETERS	AVERAGE RESULTS OF 9 MONTHS OF THE INCINERATION FEED (SOLIDS)	AVERAGE RESULTS OF 9 MONTHS OF THE INCINERATION FEED (SLUDGE)	AVERAGE RESULTS OF 9 MONTHS OF THE INCINERATION FEED (HAZARDOUS LIQUID)	RESULTS OF ONE SAMPLE OF THE WASTE FEED BEFORE INCINERATION (SLUDGE/SOLID)
PH	No Data Available	No Data Available	No Data Available	12.50
Conductivity (mS)	No Data Available	No Data Available	No Data Available	1150.00
Ash (wt%)	61.51	10.35	0.19	31.30
Loss on Ignition (wt%)	No Data Available	No Data Available	No Data Available	4.16
Moisture Content (wt%)	No Data Available	No Data Available	No Data Available	21.60
Calcium	No Data Available	No Data Available	No Data Available	20.90
Chloride	No Data Available	No Data Available	No Data Available	2.14
Iron	No Data Available	No Data Available	No Data Available	0.58
Phosphorous (mg/kg)	6.57	0.87	0.66	No Data Available
Potassium	No Data Available	No Data Available	No Data Available	0.05
Magnesium	No Data Available	No Data Available	No Data Available	0.35
Silica	No Data Available	No Data Available	No Data Available	6.50
Sodium (mg/kg)	3950.03	6745.73	89.85	6.03
Sulfur (mg/kg)	33548.54	13881.59	25879.29	42.30
Halogens (mg/kg)	10672.45	2935.03	200602.38	No Data Available
Bromine (mg/kg)	3.18	0.87	0.66	No Data Available
Chlorine (mg/kg)	10669.1	2933.86	258451.88	No Data Available
Fluorine (mg/kg)	4.99	0.87	0.66	No Data Available
Iodine (mg/kg)	0.72	0.87	0.66	No Data Available
PCB (mg/kg)	10.31	0.87	19787.96	No Data Available
Heavy Metals (mg/kg)	843.28	35.47	2.90	No Data Available
Arsenic	No Data Available	No Data Available	No Data Available	0.0074

Table (19): Comparison of Average Results of 9 Months (October 1997-June 1998) between Incineration Waste Feed and Special Sample collected On December, 1999 of Incineration Feed (continued).

PARAMETERS	AVERAGE RESULTS OF 9 MONTHS OF THE INCINERATION FEED (SOLIDS)	AVERAGE RESULTS OF 9 MONTHS OF THE INCINERATION FEED (SLUDGE)	AVERAGE RESULTS OF 9 MONTHS OF THE INCINERATION FEED (HAZARDOUS LIQUID)	RESULTS OF ONE SAMPLE OF THE WASTE FEED BEFORE INCINERATION (SLUDGE/SOLID)
Cadmium	No Data Available	No Data Available	No Data Available	0.01
Chromium Total	No Data Available	No Data Available	No Data Available	0.04
Lead	No Data Available	No Data Available	No Data Available	0.10
Mercury	No Data Available	No Data Available	No Data Available	0.0034
Zinc	No Data Available	No Data Available	No Data Available	0.19

Tablc (20): Comparison of Average Results of 9 Months (October 1997-June 1998) between Ash Solids After Incineration and Special Sample collected On December, 1999 of Ash After Incineration.

PARAMETERS	AVERAGE RESULTS OF 9 MONTHS OF THE ASH SOLIDS AFTER INCINERATION	RESULTS OF ONE SAMPLE OF THE ASH MATERIAL AFTER INCINERATION
Ph	No Data Available	11.30
Conductivity (mS)	No Data Available	8500.00
Ash (wt%)	No Data Available	98.00
Loss on Ignition (wt%)	10.36	2.46
Moisture Content (wt%)	No Data Available	0.03
Calcium (mg/kg)	151250.00	21.50
Chloride	No Data Available	0.36
Iron (mg/kg)	No Data Available	0.61
Magnesium (mg/kg)	No Data Available	1.17
Silica	No Data Available	3.82
Sodium (mg/kg)	12500.00	0.30
Sulfur (mg/kg)	5333.00	0.80
TOC (mg/kg)	<0.10	No Data Available
Chlorine (mg/kg)	6636.00	No Data Available
Arsenic (mg/kg)	<0.01	0.0014
Cadmium (mg/kg)	3.19	0.04
Chromium Total (mg/kg)	46.23	0.11
Lead (mg/kg)	36.26	0.11
Mercury (mg/kg)	<0.01	0.0025
Zinc (mg/kg)	No Data Available	0.03

FIGURE (3) INCINERATION WASTE QUANTITES

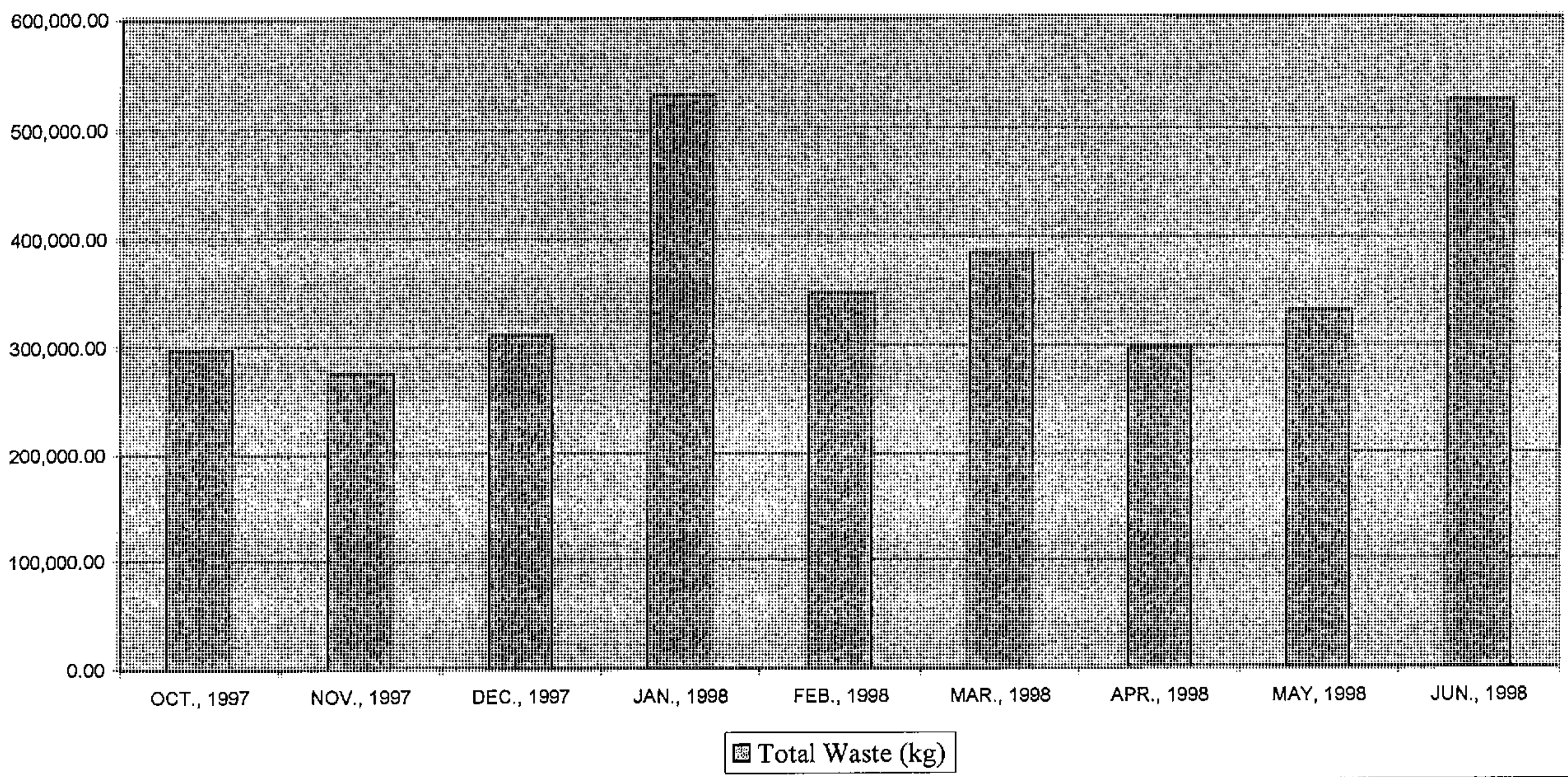


FIGURE (4) INCINERATION FEED ANALYSIS (SOLIDS)

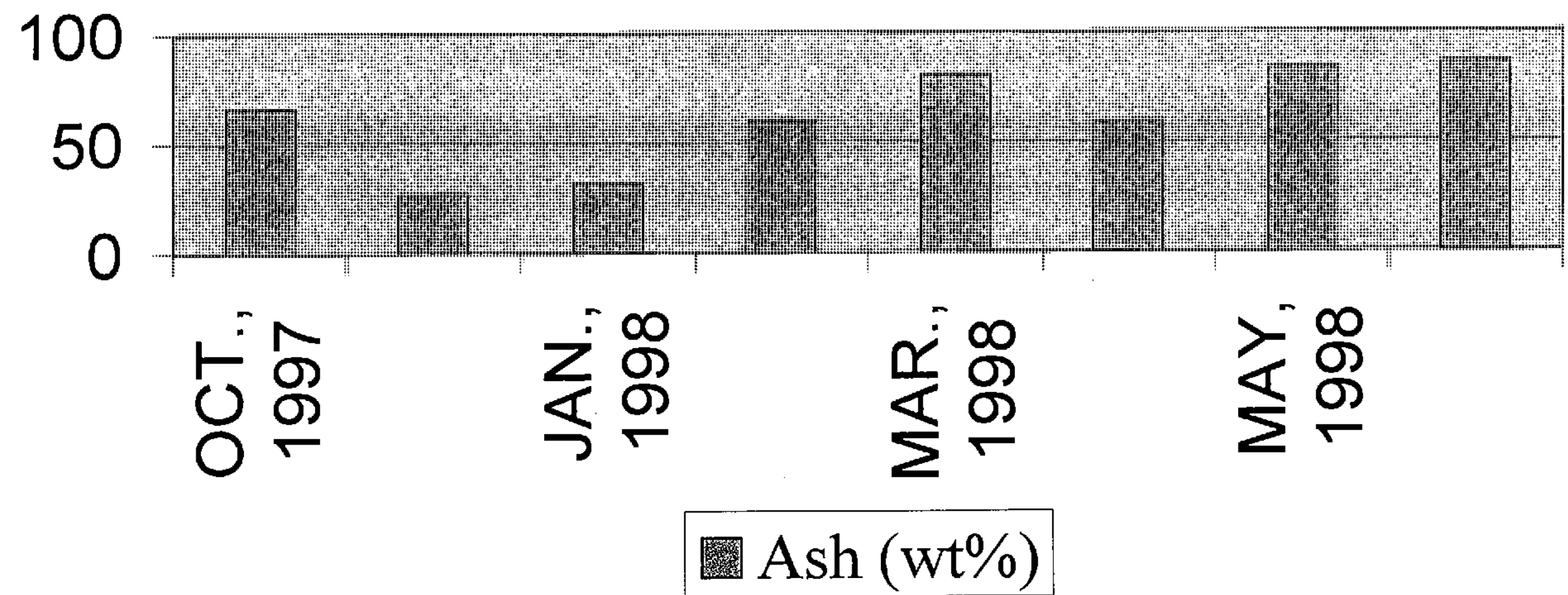


FIGURE (5) INCINERATION FEED ANALYSIS (SOLIDS)

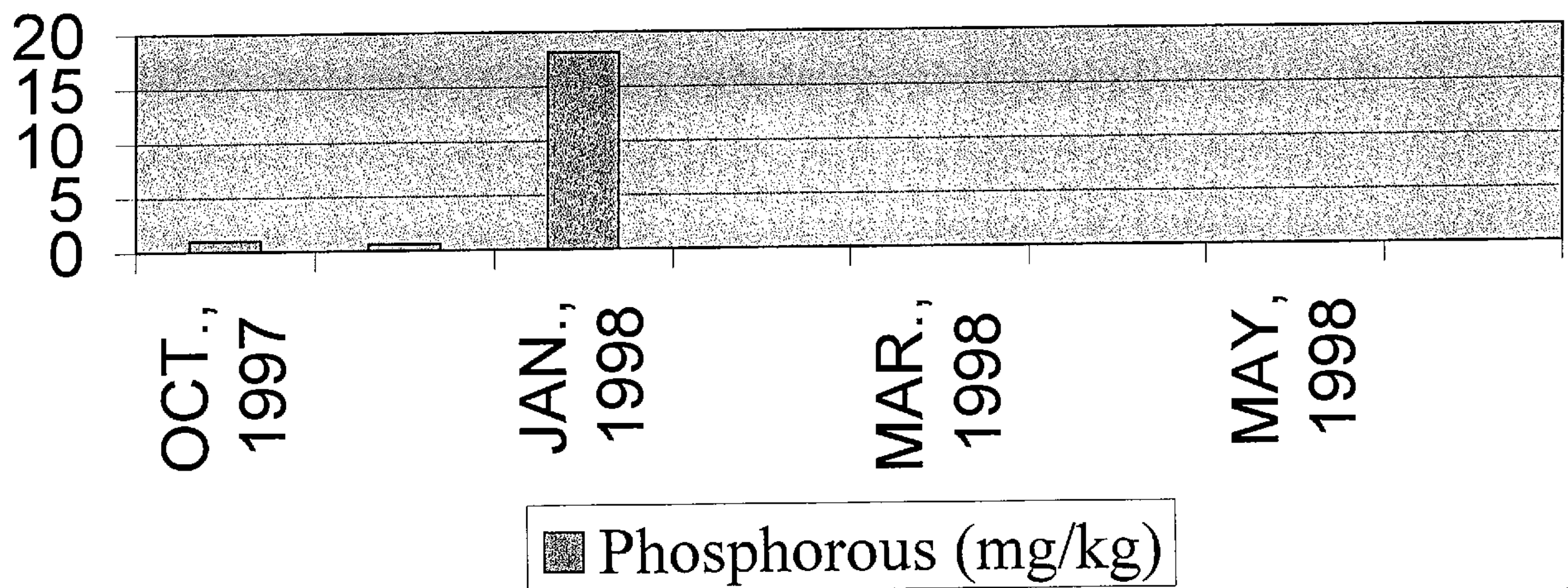


FIGURE (6) INCINERATION FEED ANALYSIS (SOLIDS)

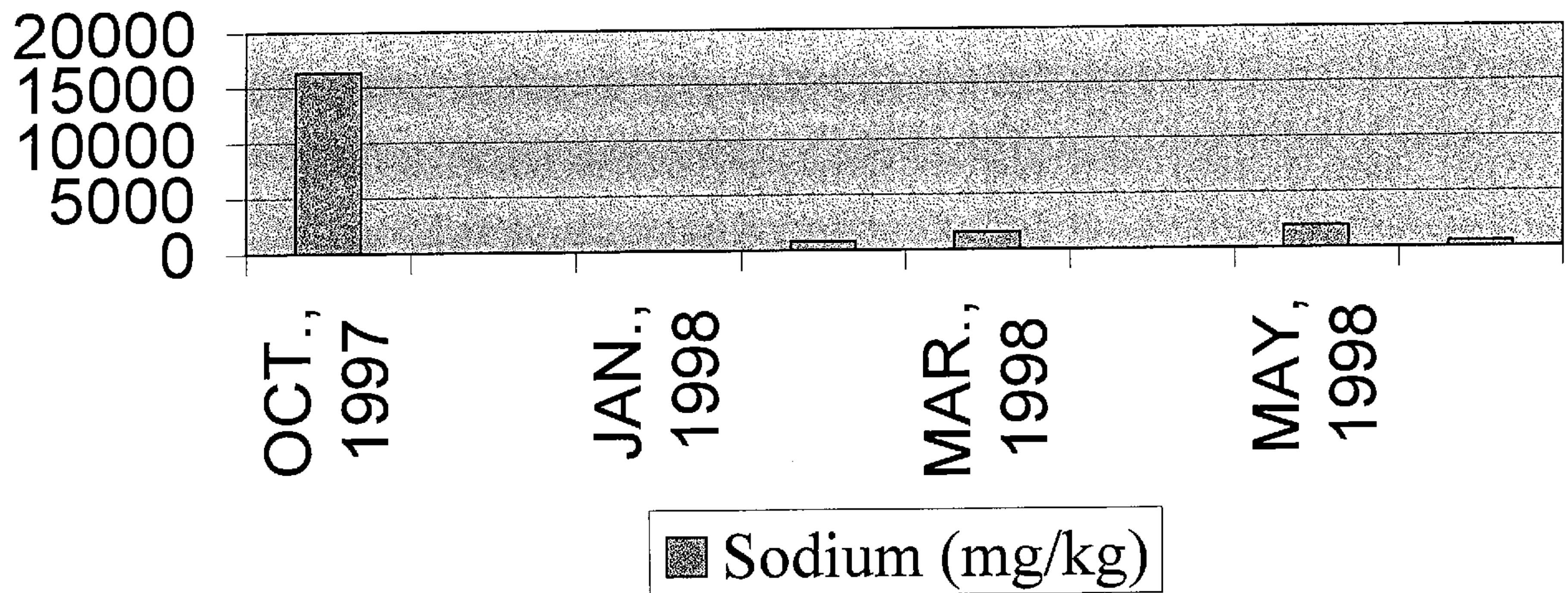


FIGURE (7) INCINERATION FEED ANAYSIS (SOLIDS)

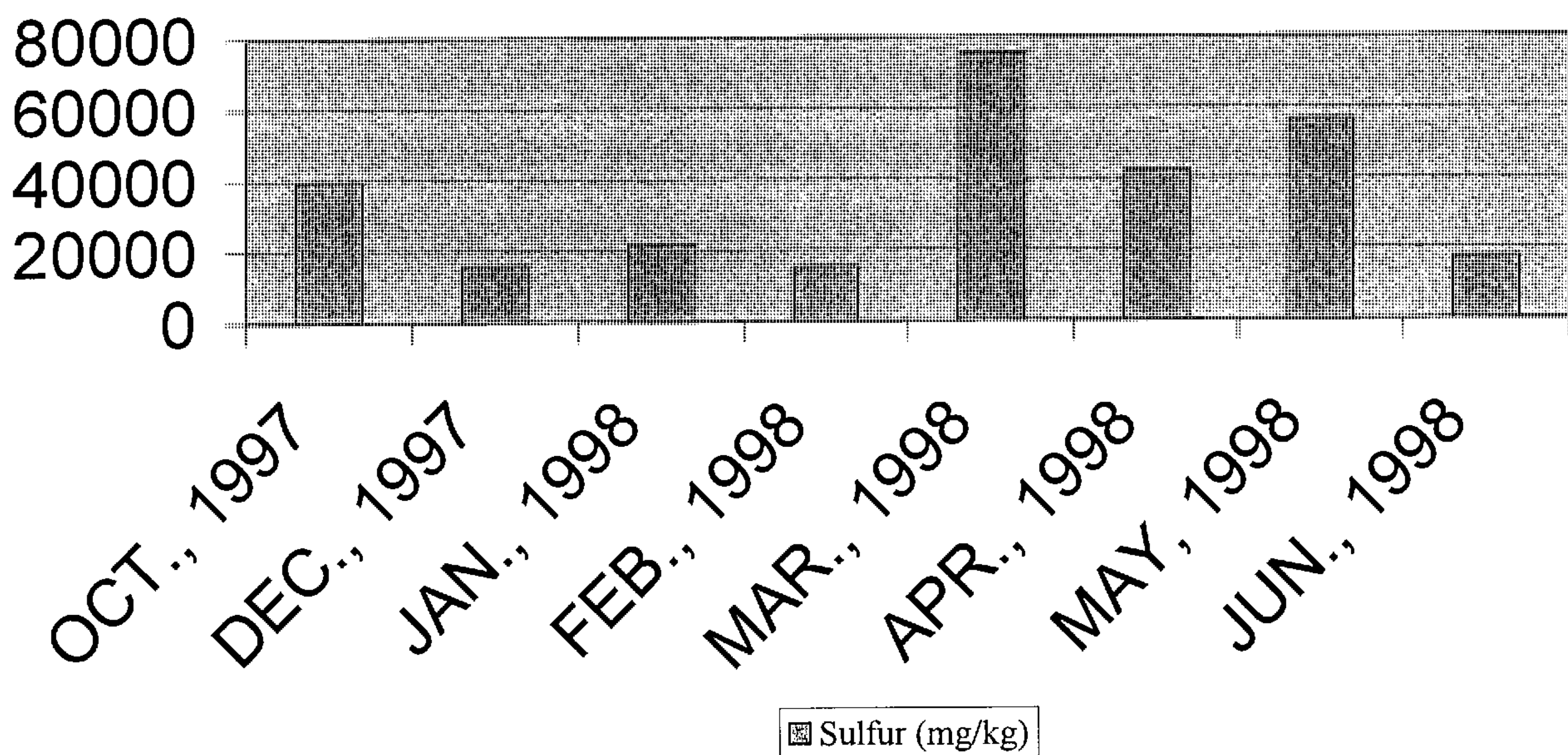


FIGURE (8) INCINERATION FEED ANALYSIS (SOLIDS)

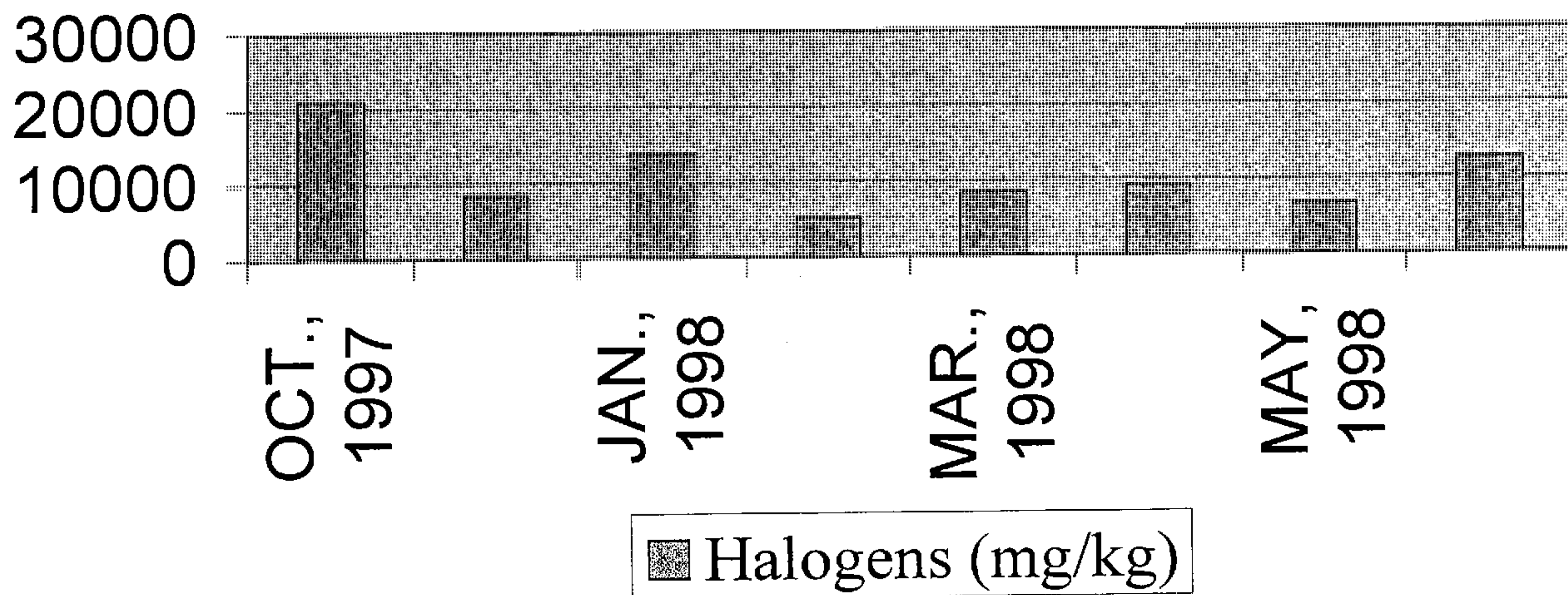


FIGURE (9) INCINERATION FEED ANALYSIS (SOLIDS)

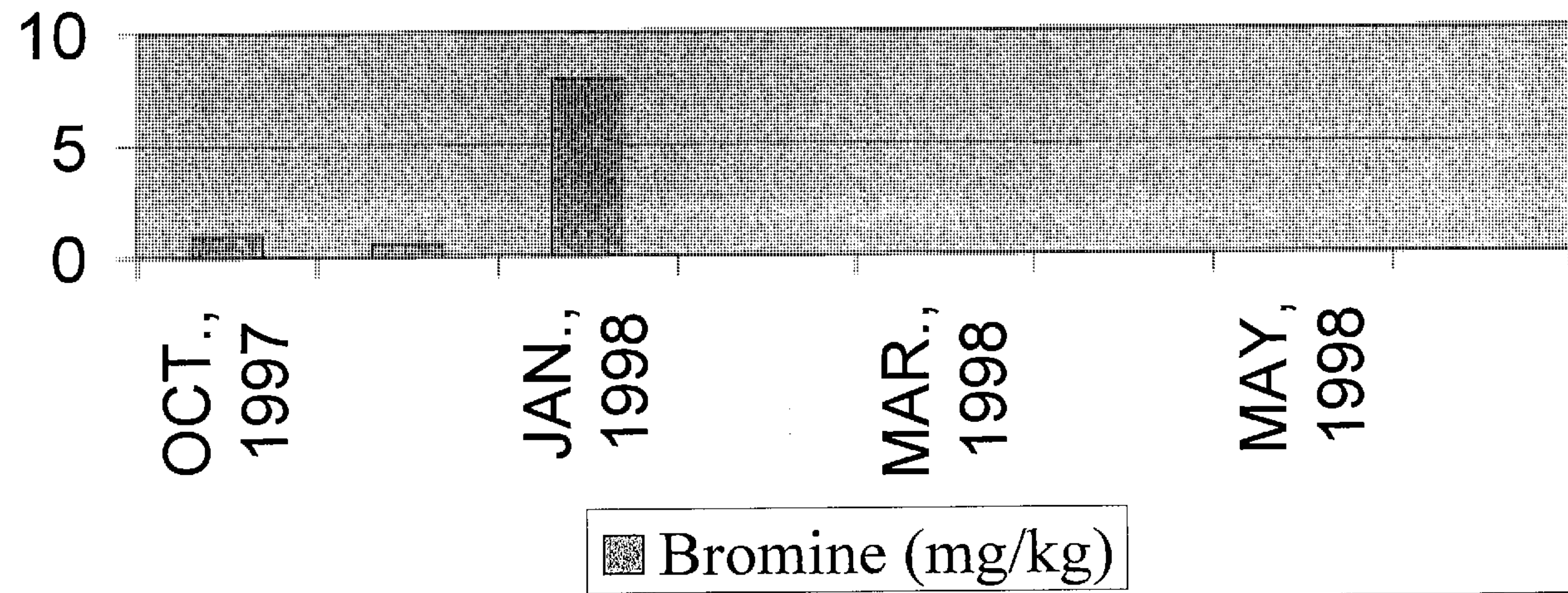
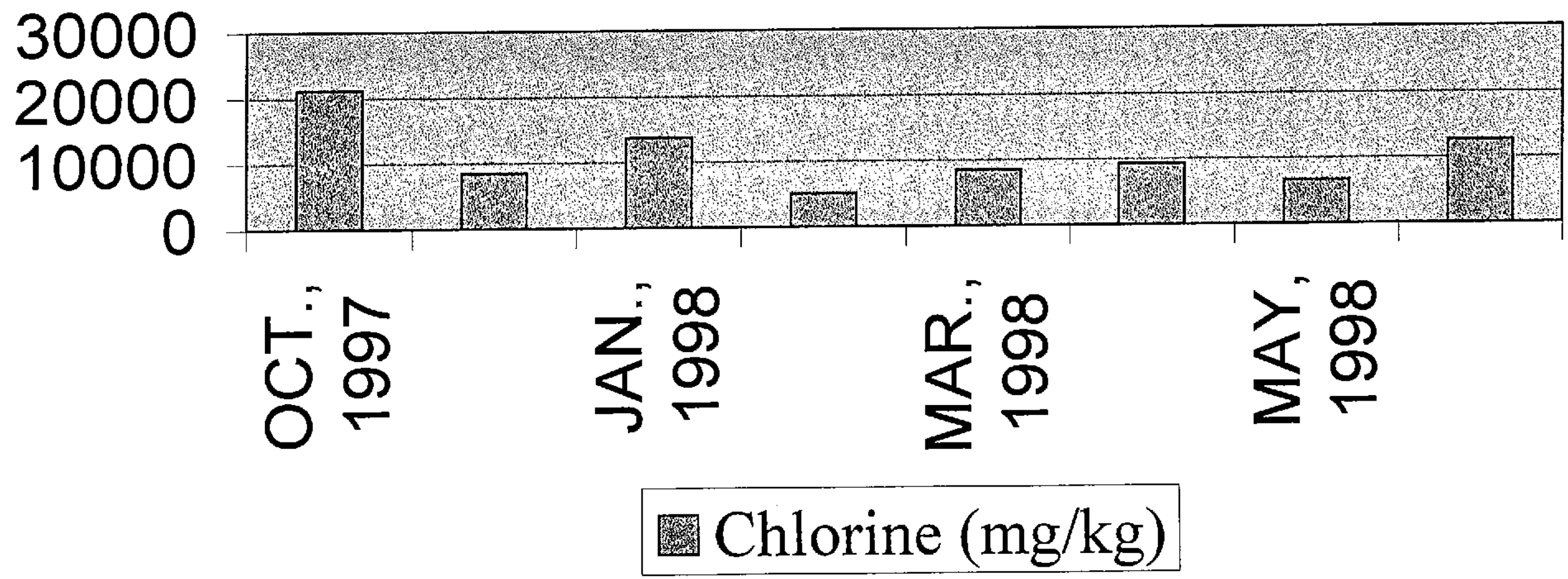
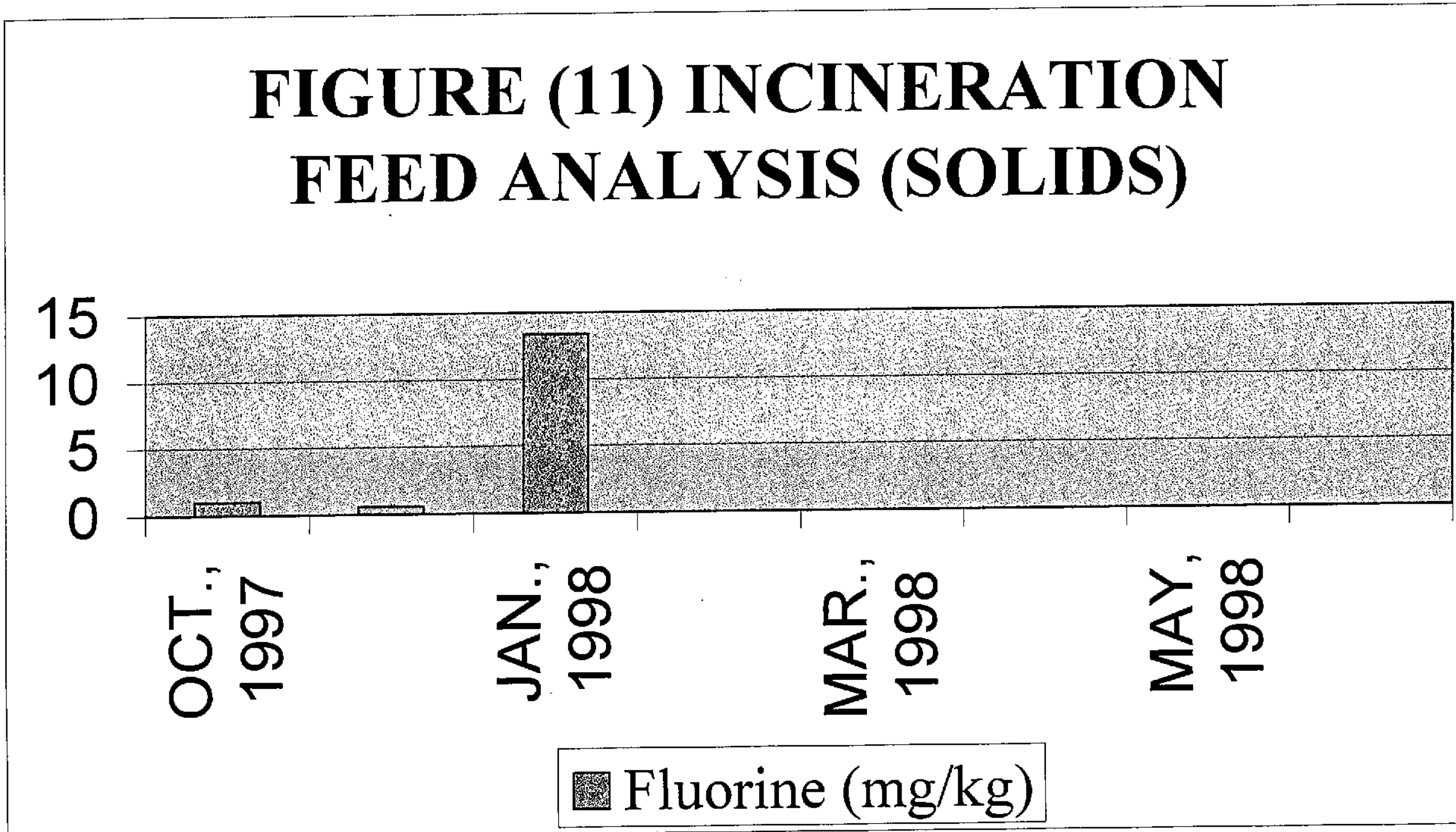


FIGURE (10) INCINERATION FEED ANALYSIS (SOLIDS)




FIGURE (11) INCINERATION FEED ANALYSIS (SOLIDS)
15
10
5
0
OCT., 1997
JAN., 1998
MAR., 1998
MAY, 1998
Fluorine (mg/kg)

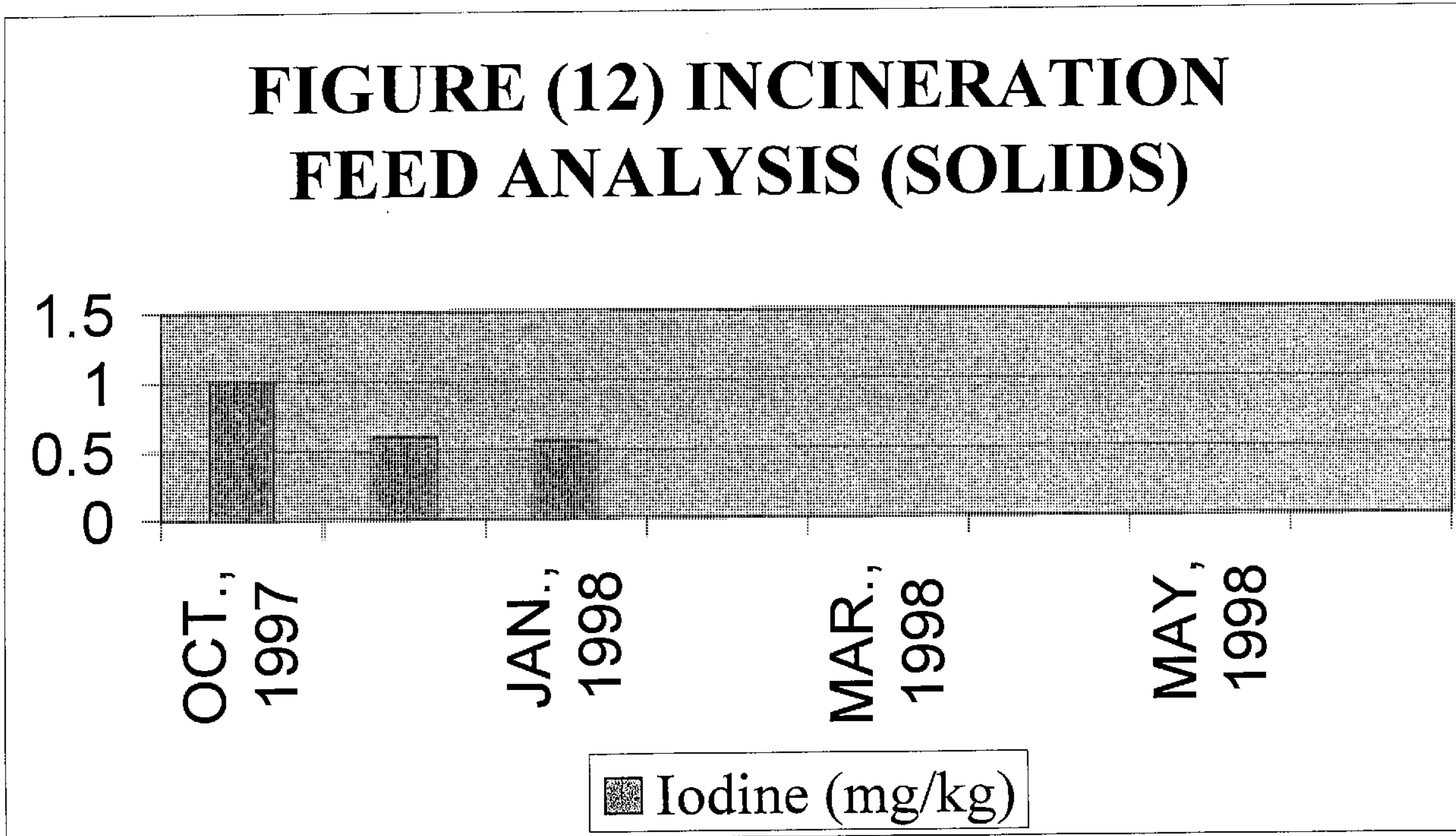

FIGURE (12) INCINERATION FEED ANALYSIS (SOLIDS)
1.5
1
0.5
0
OCT., 1997
JAN., 1998
MAR., 1998
MAY, 1998
Iodine (mg/kg)

FIGURE (13) INCINERATION FEED ANALYSIS (SOLIDS)

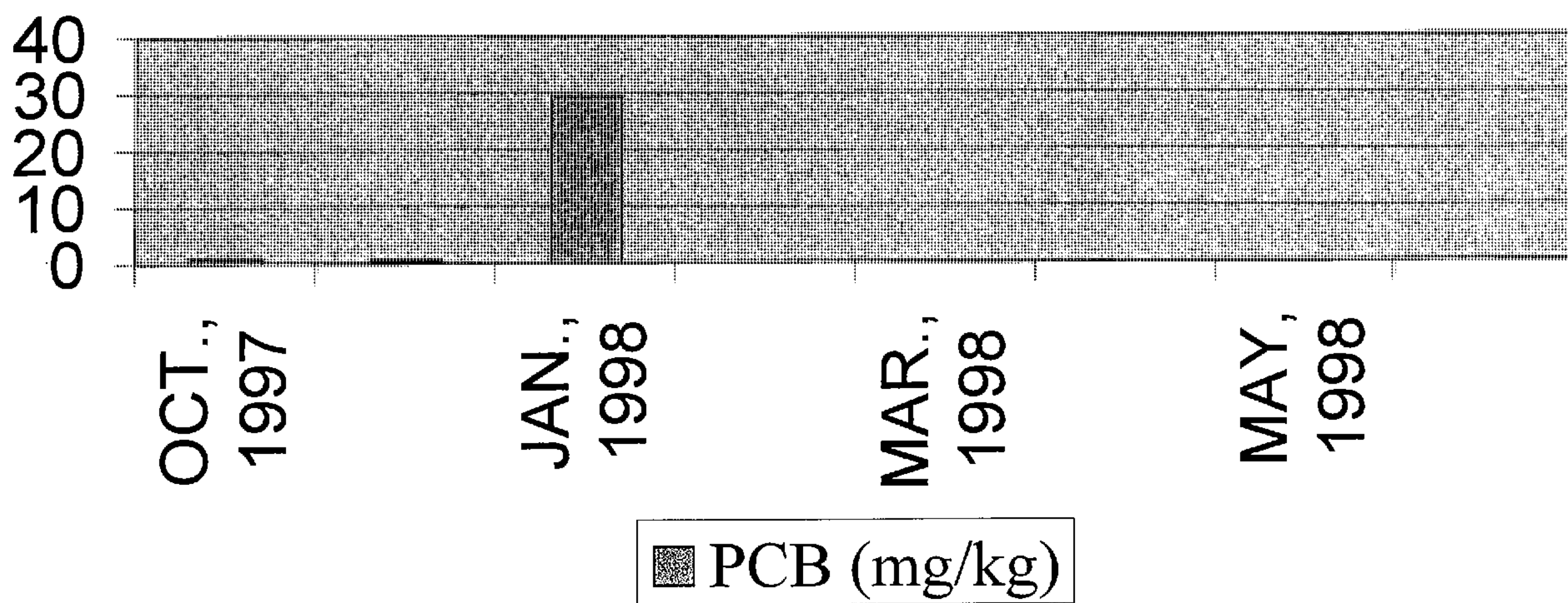
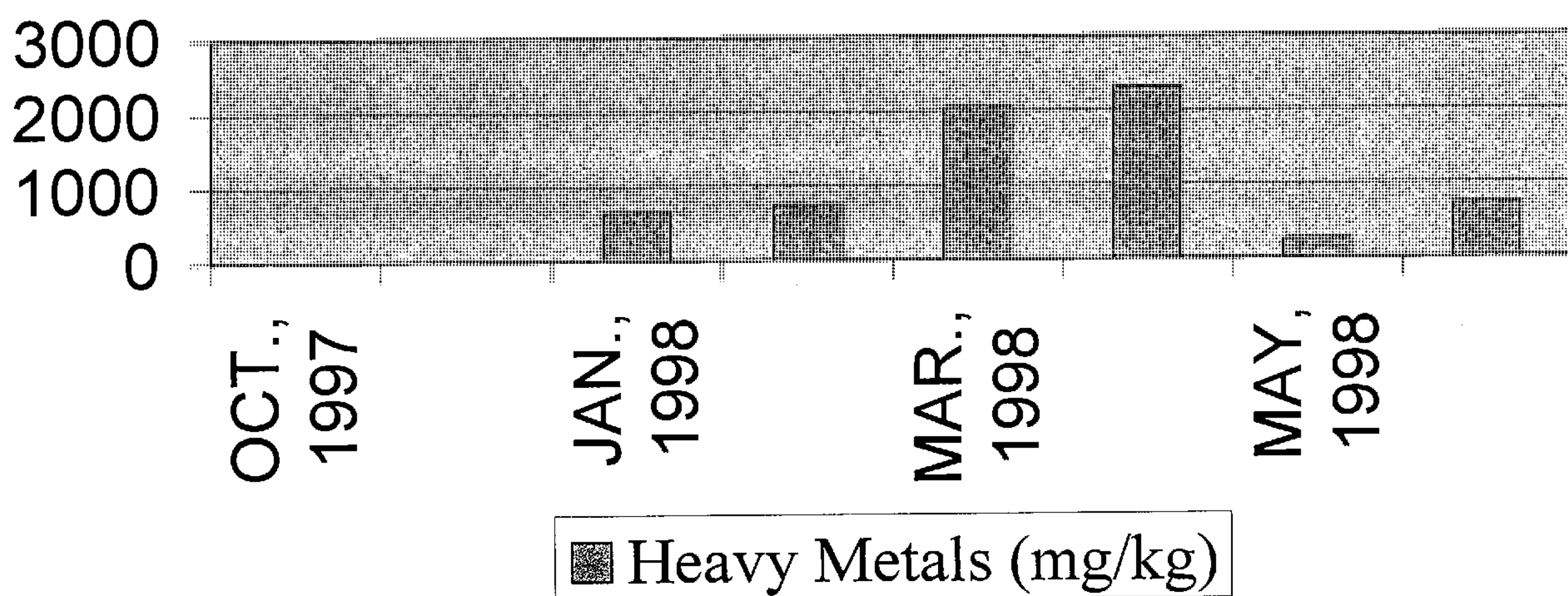


FIGURE (14) INCINERATION FEED ANALYSIS (SOLIDS)



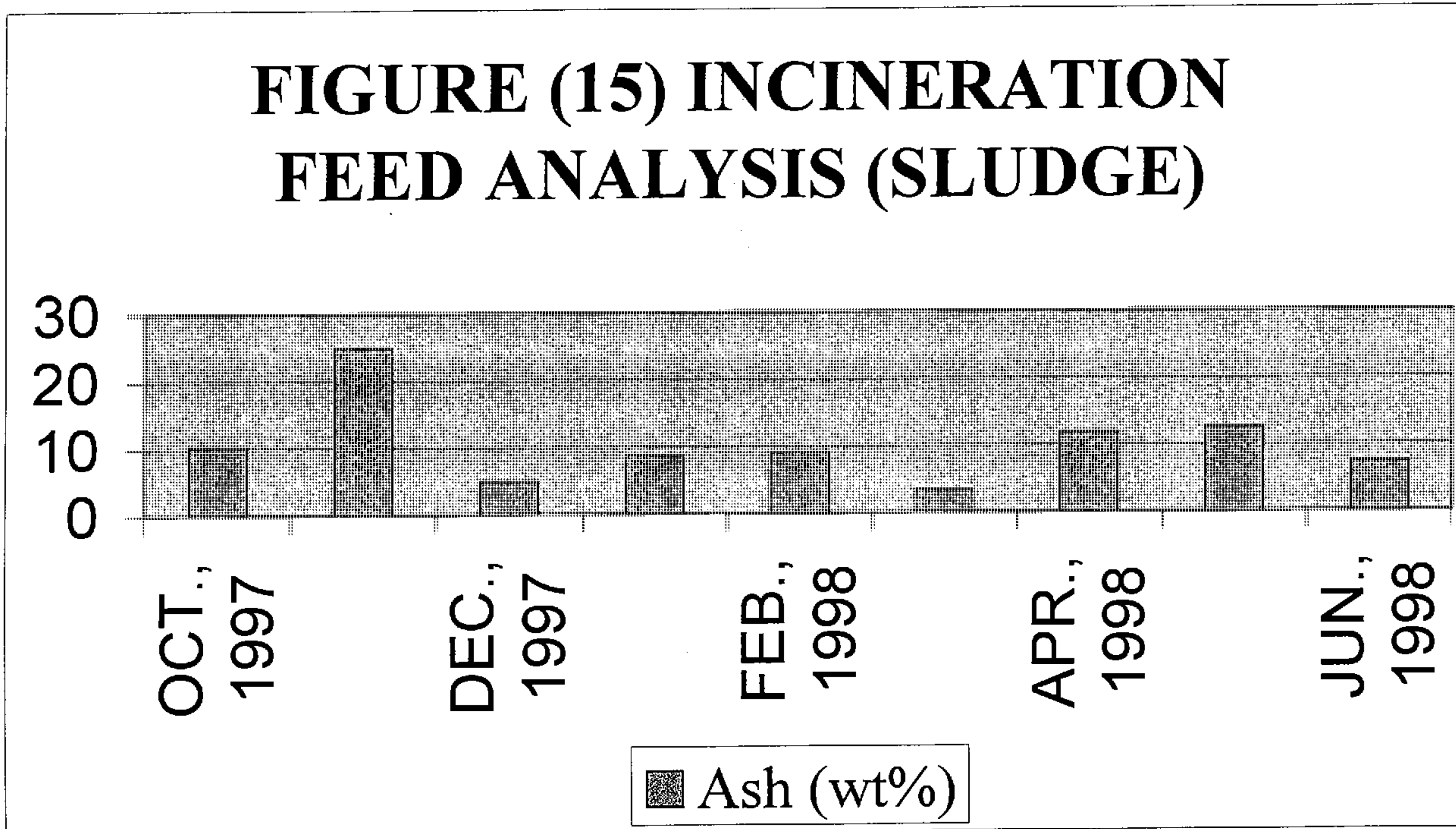

FIGURE (15) INCINERATION
FEED ANALYSIS (SLUDGE)
30
20
10
0
OCT., 1997
DEC., 1997
FEB., 1998
APR., 1998
JUN., 1998
Ash (wt%)

FIGURE (16) INCINERATION FEED ANALYSIS (SLUDGE)

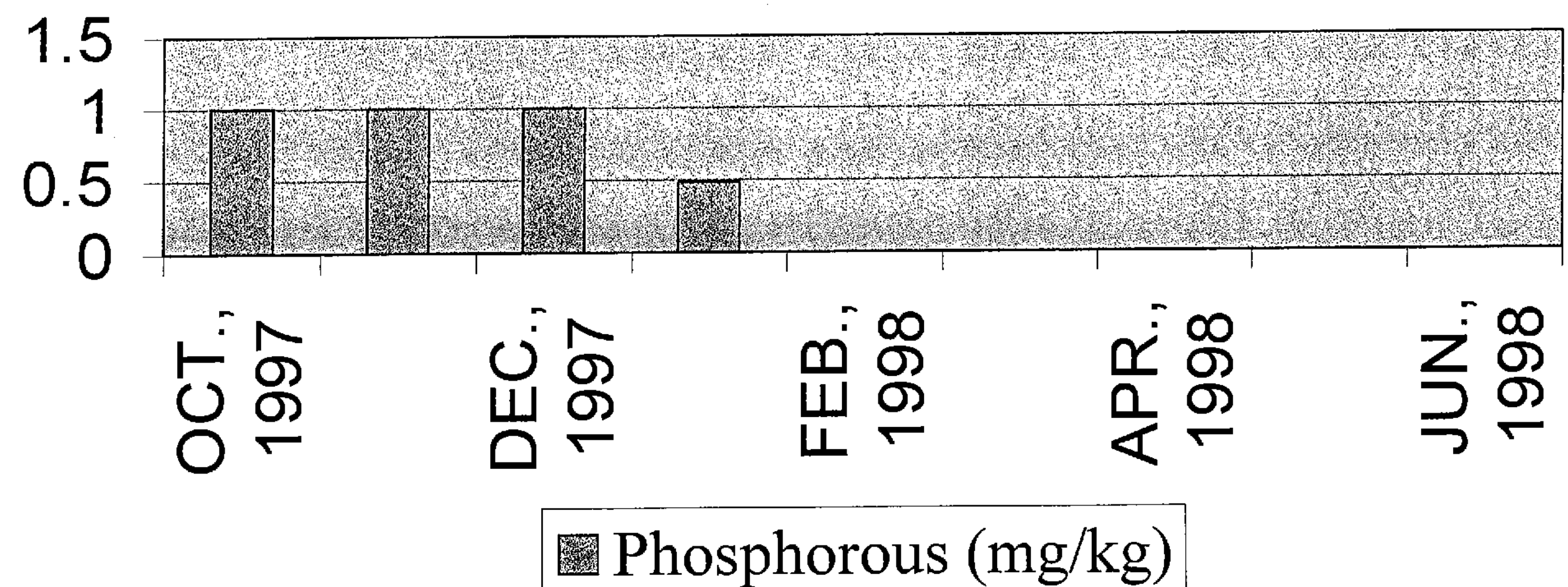


FIGURE (17) INCINERATION FEED ANALYSIS (SLUDGE)

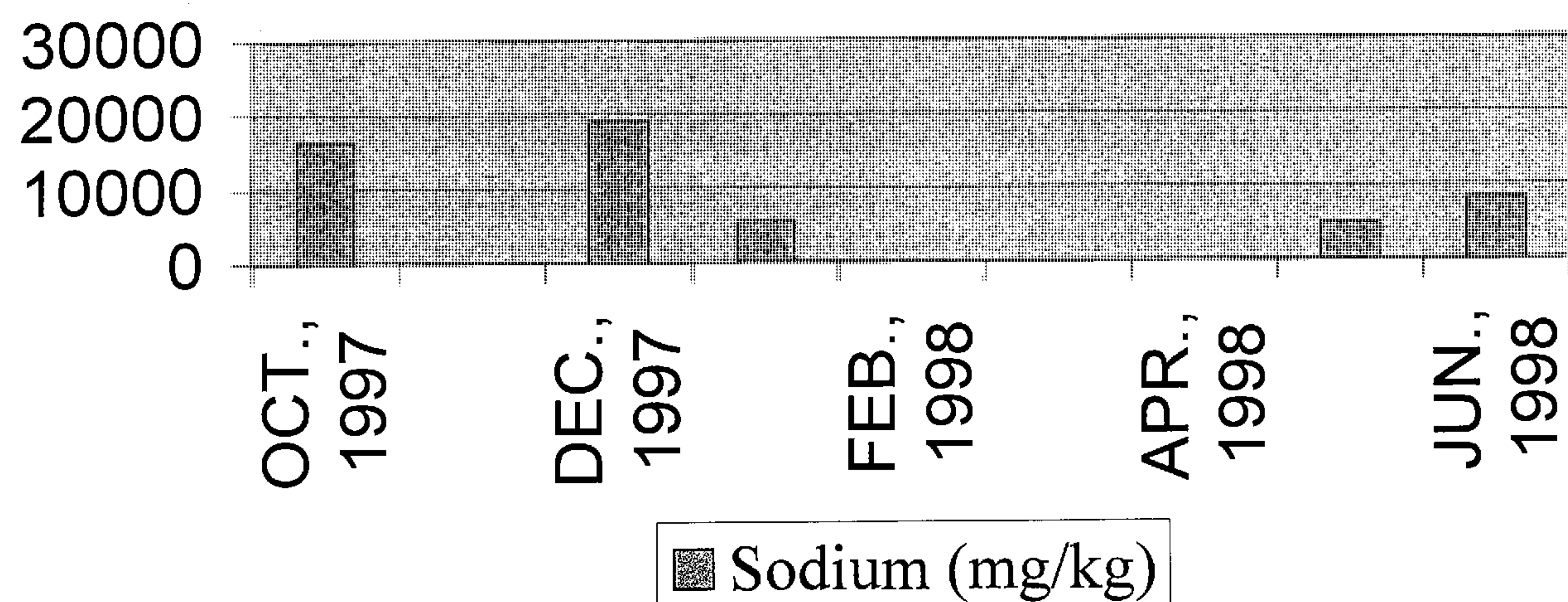


FIGURE (18) INCINERATION FEED ANALYSIS (SLUDGE)

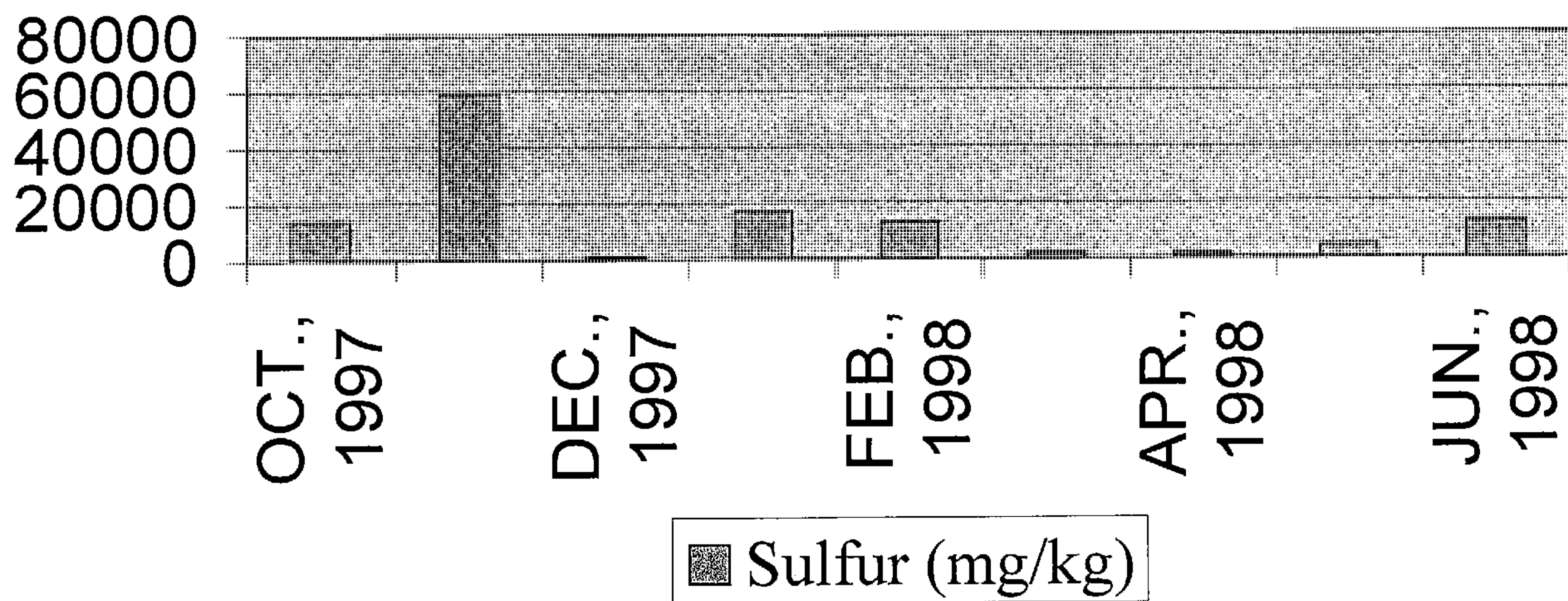
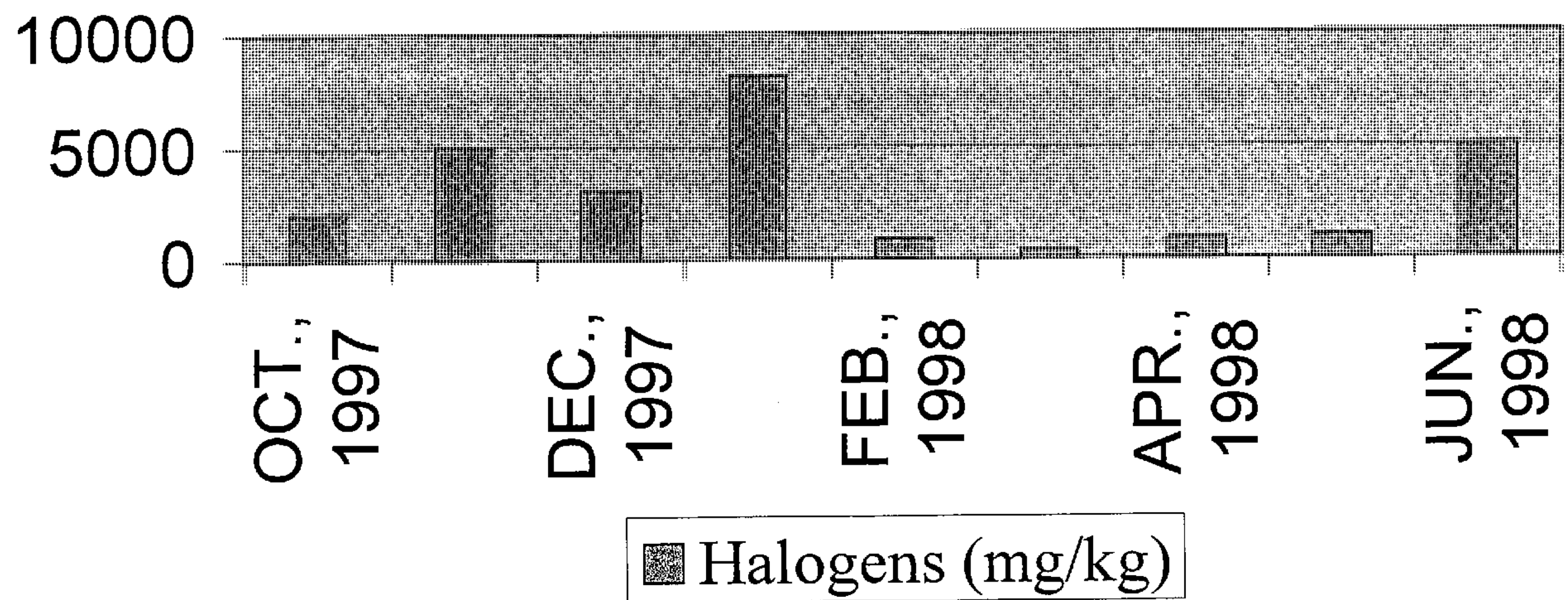


FIGURE (19) INCINERATION FEED ANALYSIS (SLUDGE)



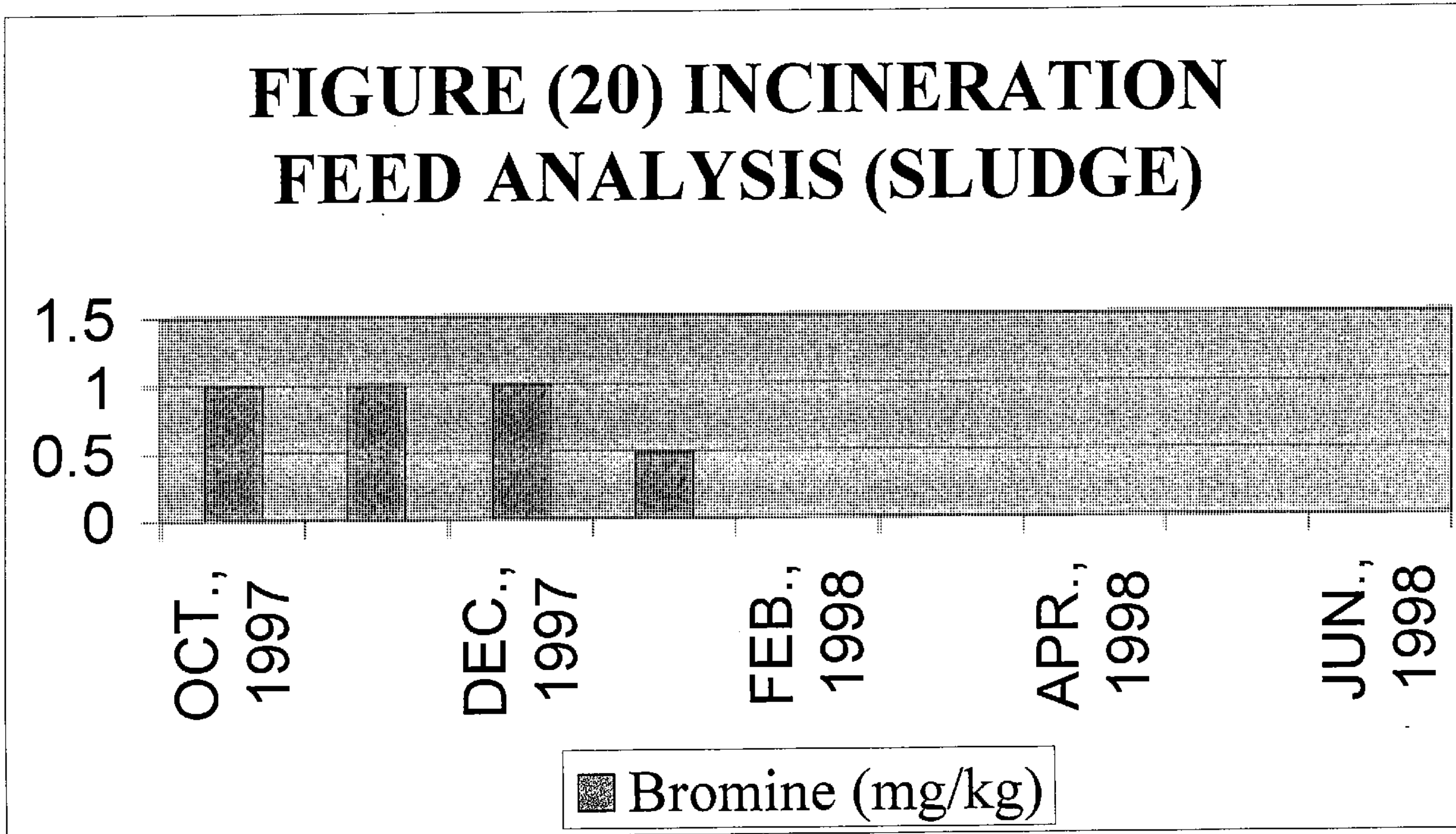

FIGURE (20) INCINERATION
FEED ANALYSIS (SLUDGE)
1.5
1
0.5
0
OCT., 1997
DEC., 1997
FEB., 1998
APR., 1998
JUN., 1998
Bromine (mg/kg)

FIGURE (21) INCINERATION FEED ANALYSIS (SLUDGE)

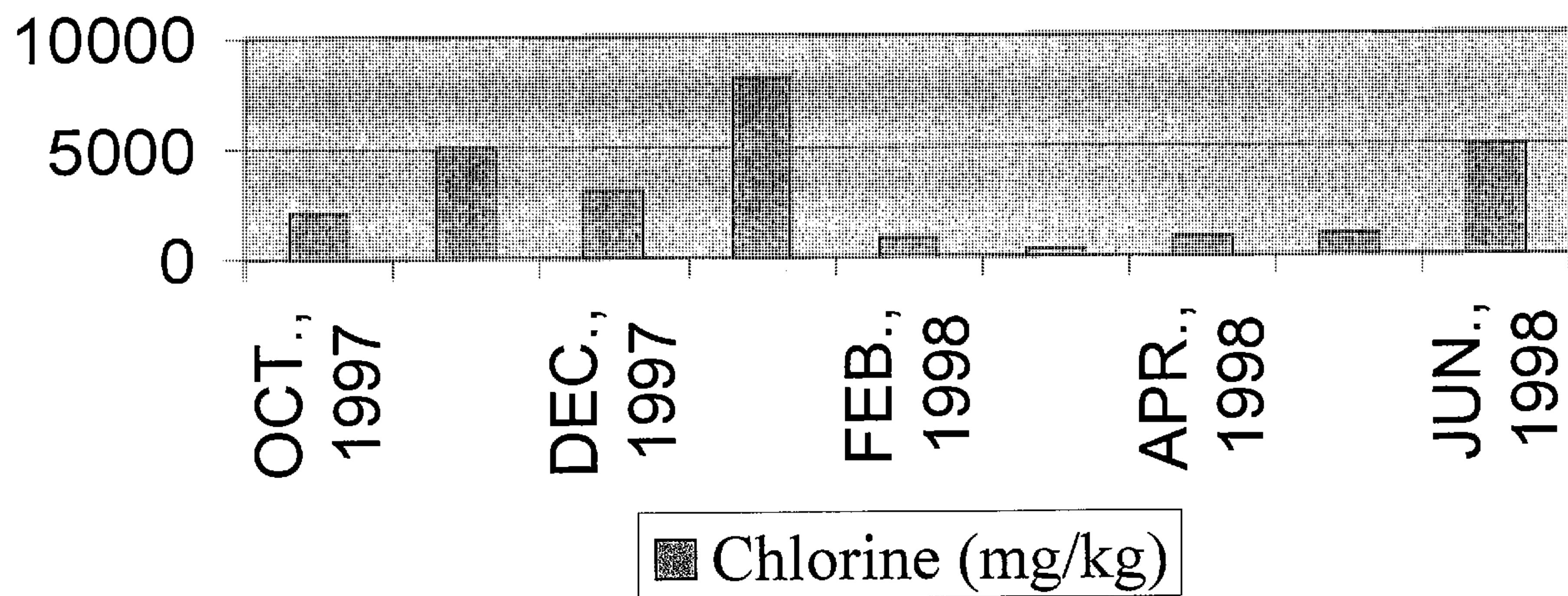
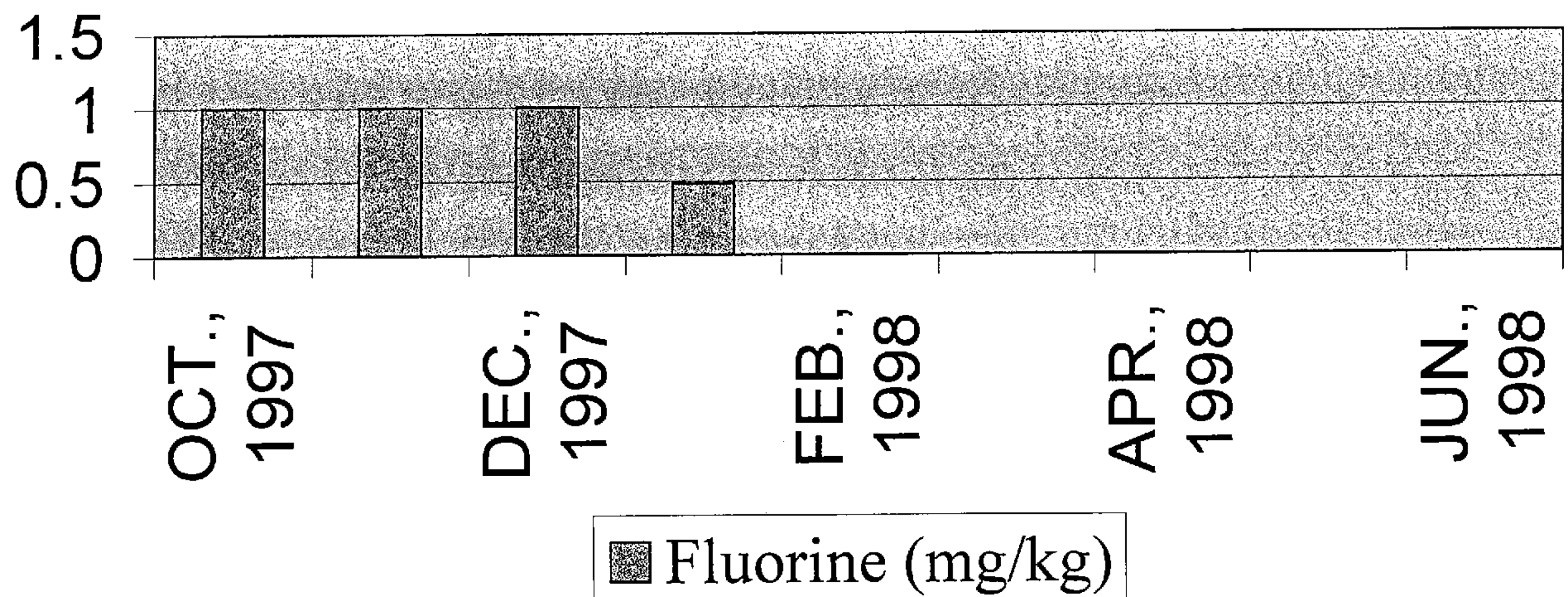


FIGURE (22) INCINERATION FEED ANALYSIS (SLUDGE)



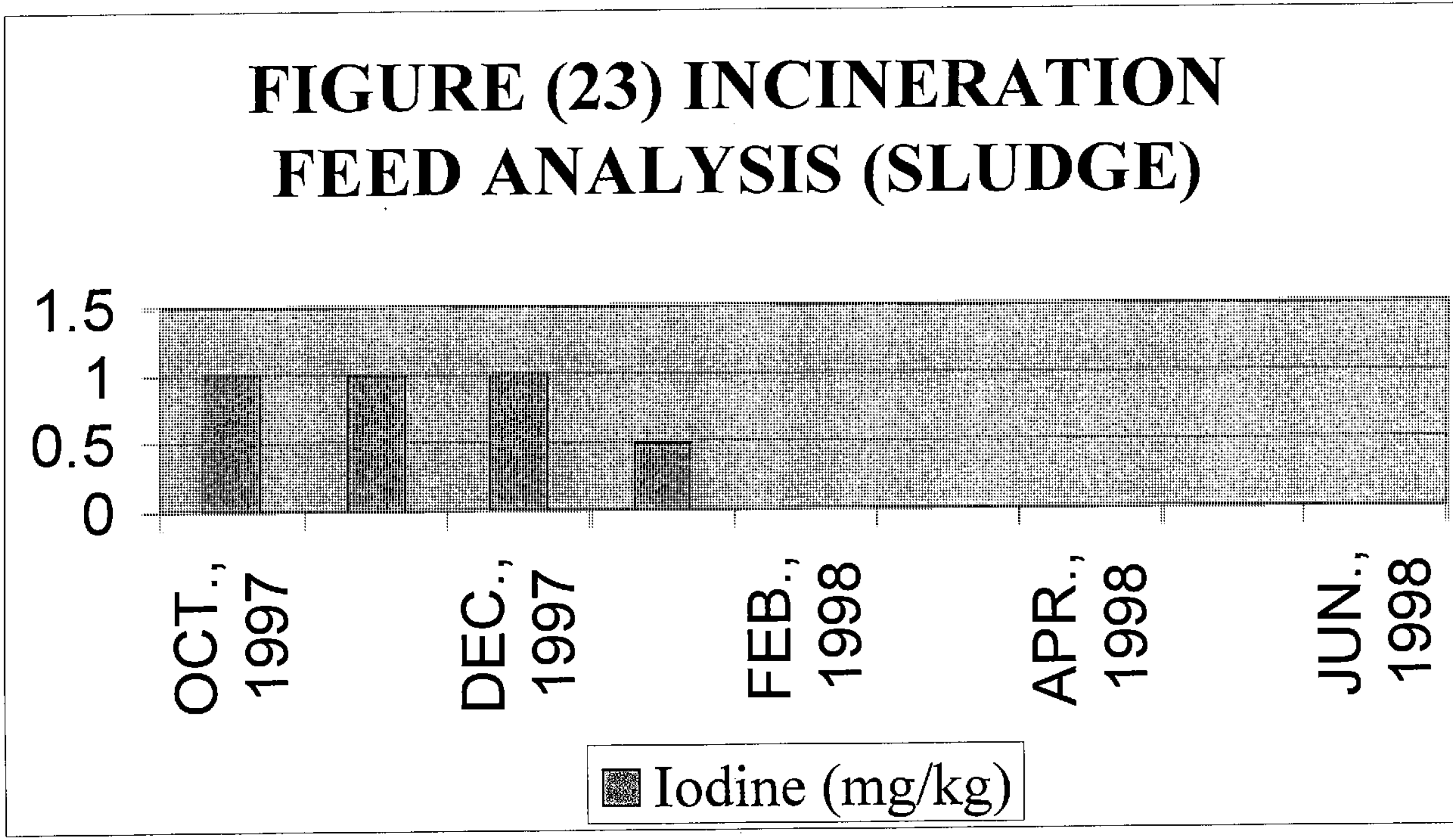


FIGURE (23) INCINERATION
FEED ANALYSIS (SLUDGE)
1.5
1
0.5
0
OCT., 1997
DEC., 1997
FEB., 1998
APR., 1998
JUN., 1998
Iodine (mg/kg)

FIGURE (24) INCINERATION FEED ANALYSIS (SLUDGE)

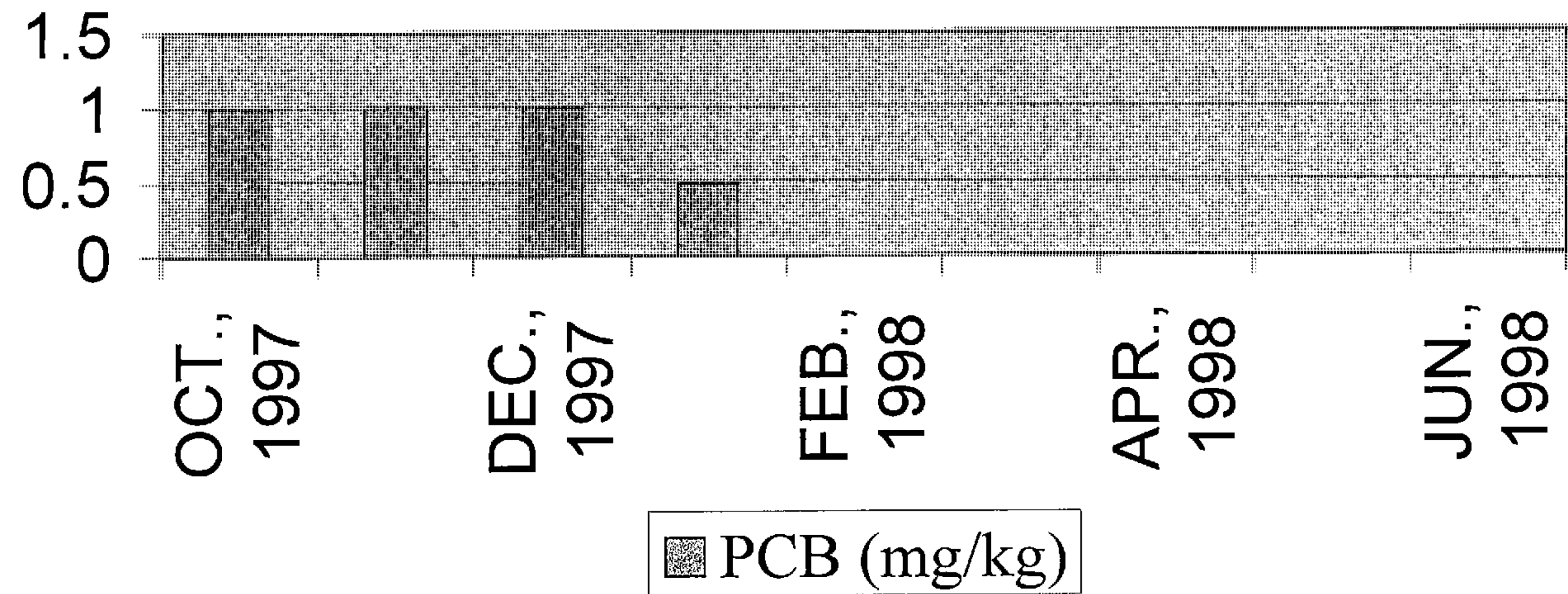


FIGURE (25) INCINERATION FEED ANALYSIS (SLUDGE)

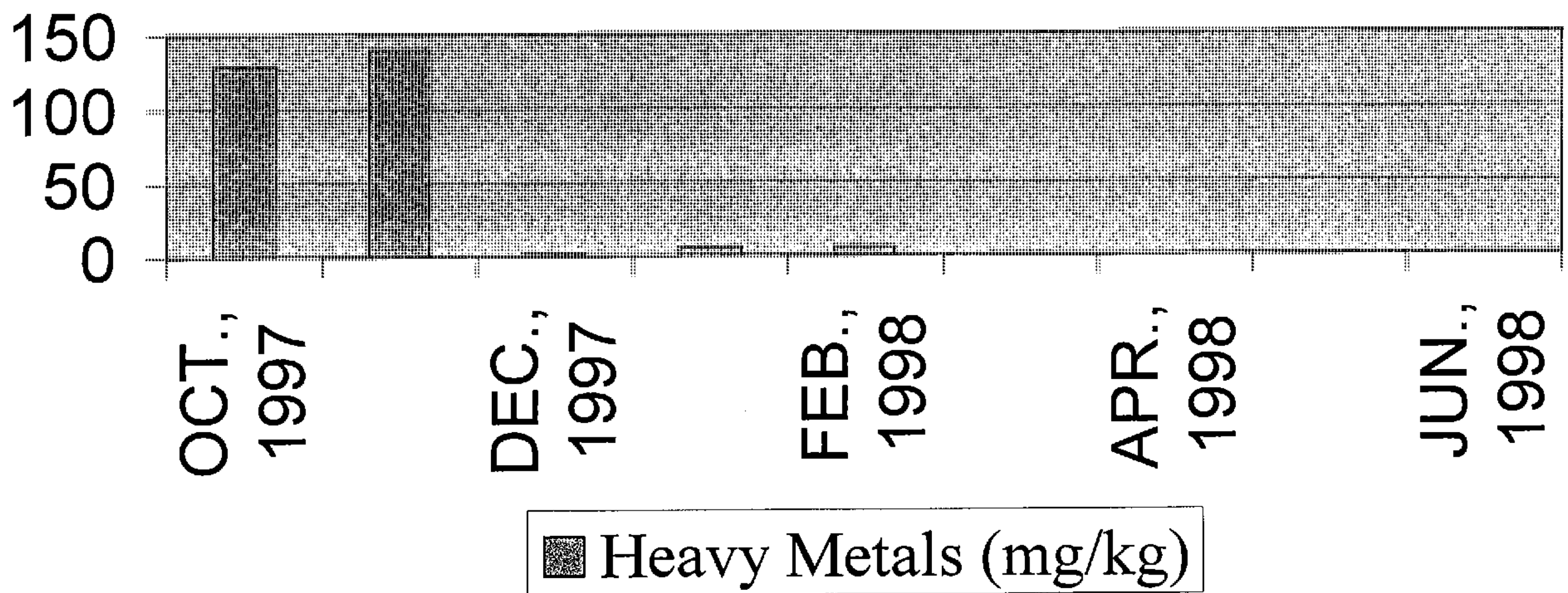


FIGURE (26) INCINERATION FEED ANALYSIS (HAZARDOUS LIQUID)

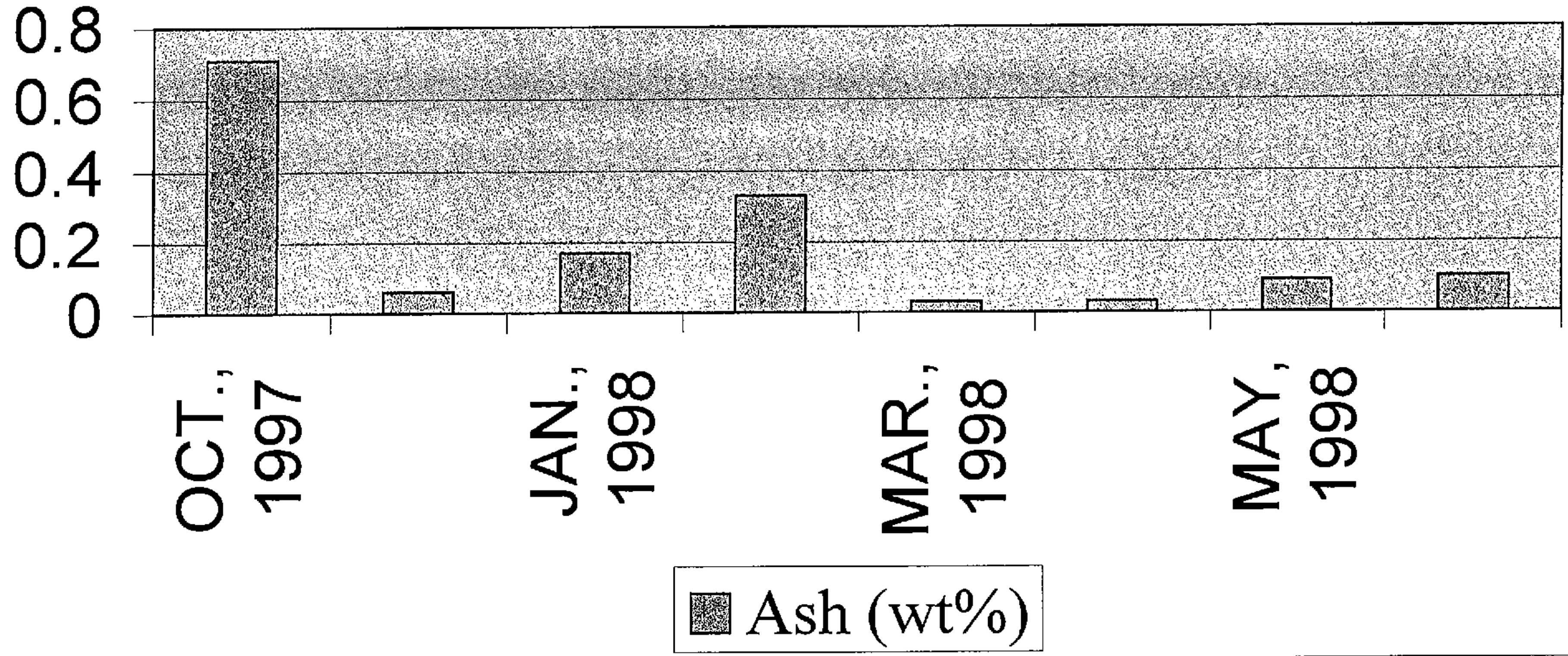


FIGURE (27) INCINERATION FEED ANALYSIS (HAZARDOUS LIQUID)

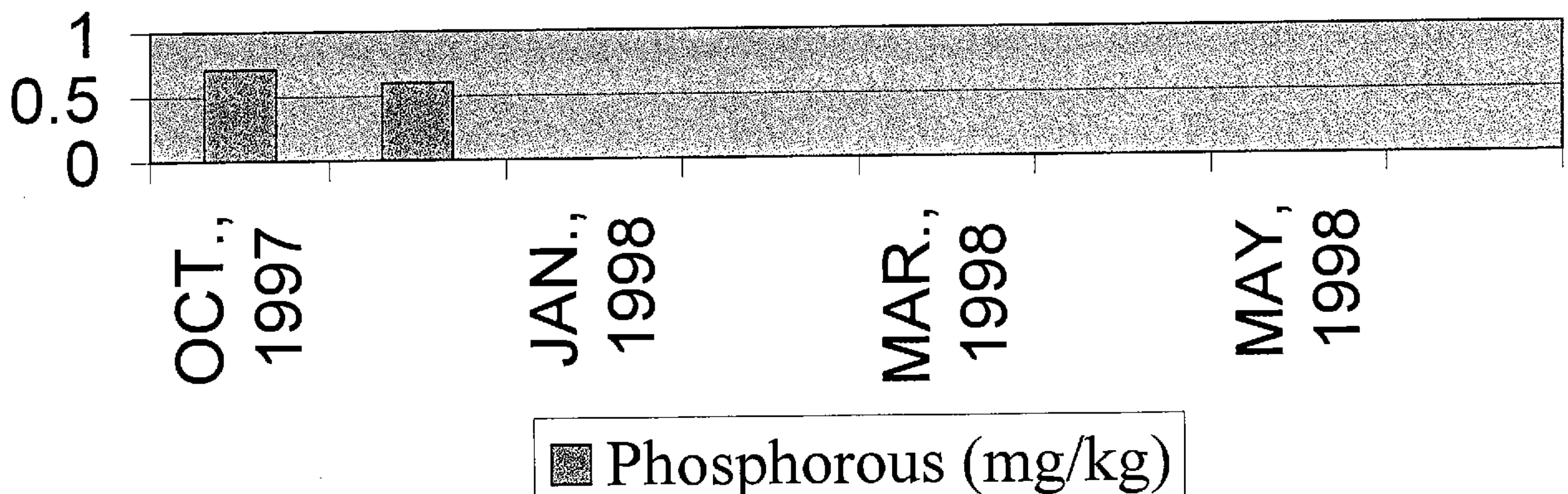


FIGURE (28) INCINERATION FEED ANALYSIS (HAZARDOUS LIQUID)

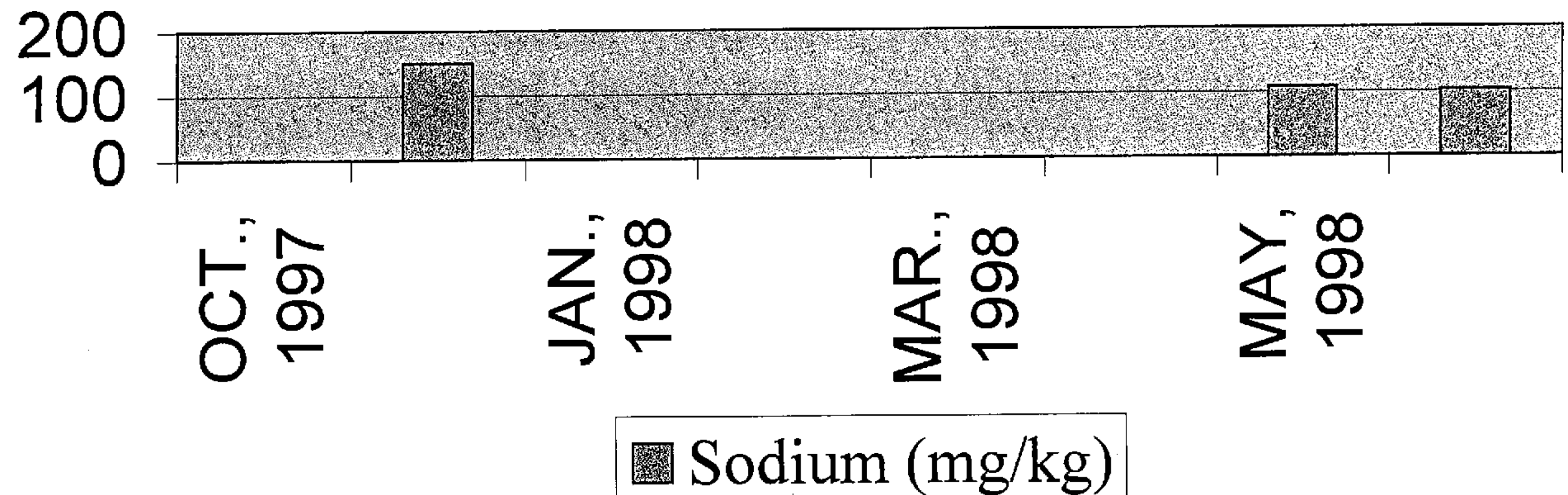


FIGURE (29) INCINERATION FEED ANALYSIS (HAZARDOUS LIQUID)

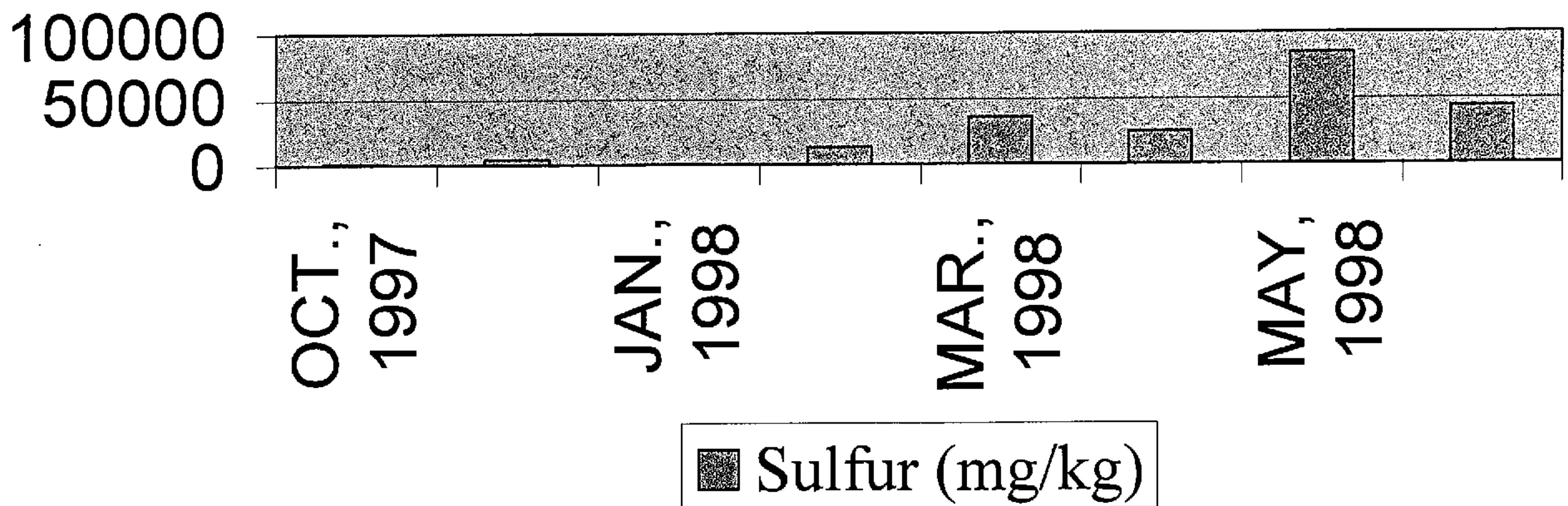


FIGURE (30) INCINERATION FEED ANALYSIS (HAZARDOUS LIQUID)

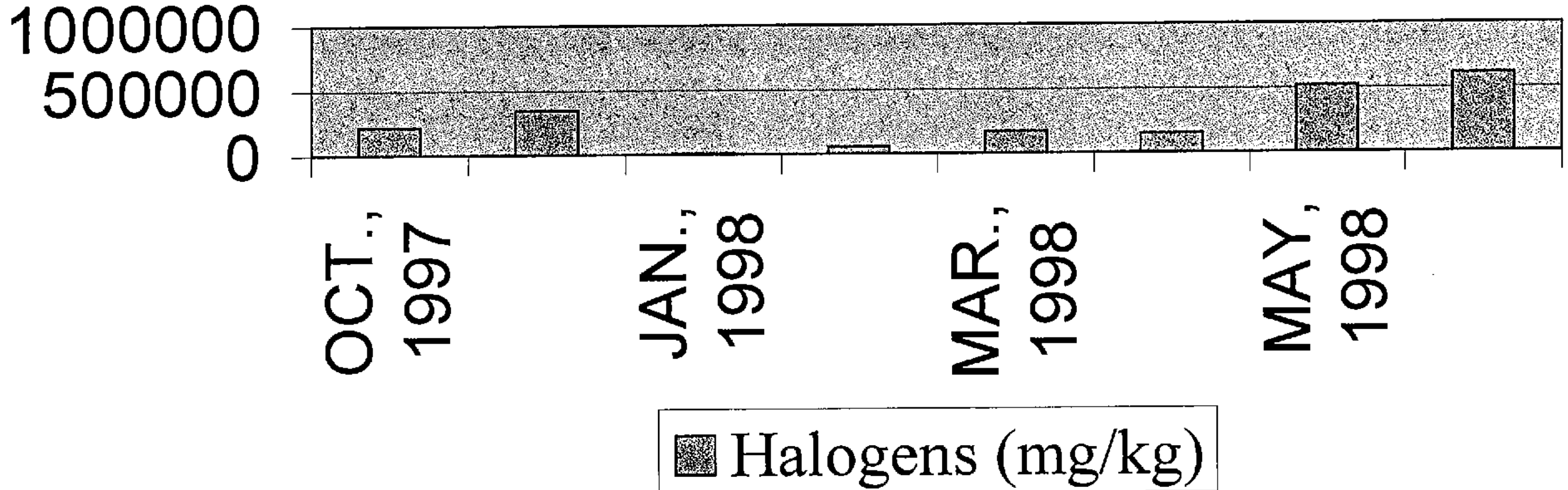


FIGURE (31) INCINERATION FEED ANALYSIS (HAZARDOUS LIQUID)

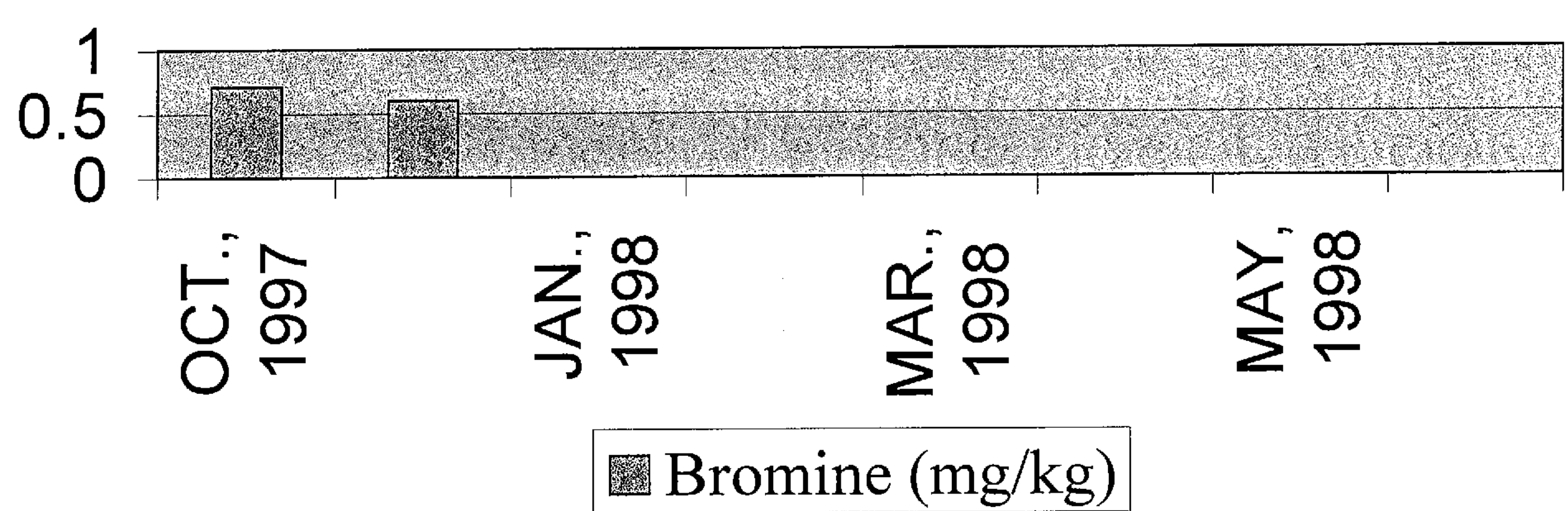


FIGURE (32) INCINERATION FEED ANALYSIS (HAZARDOUS LIQUID)

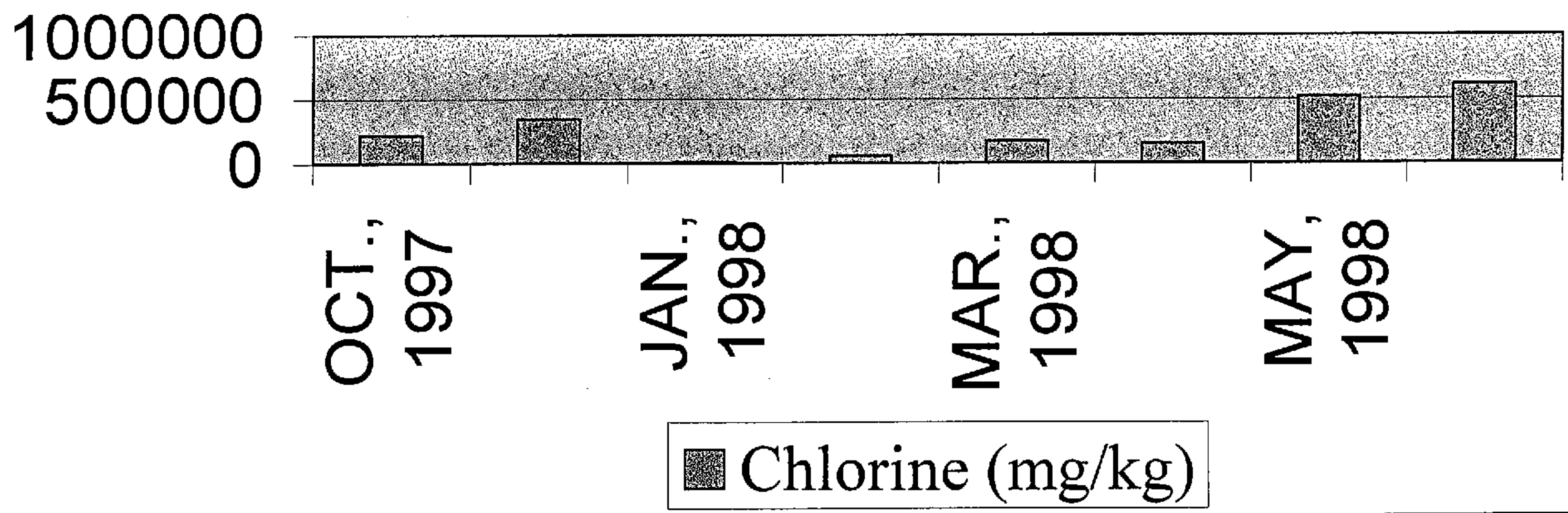


FIGURE (33) INCINERATION FEED ANALYSIS (HAZARDOUS LIQUID)

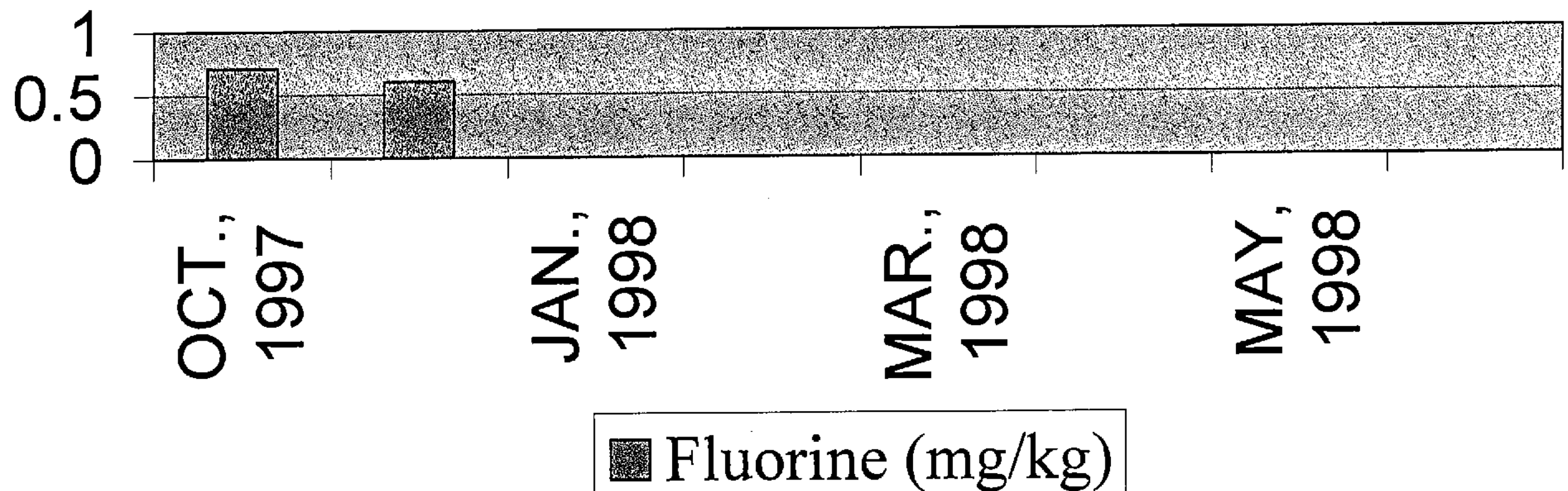


FIGURE (34) INCINERATION FEED ANALYSIS (HAZARDOUS LIQUID)

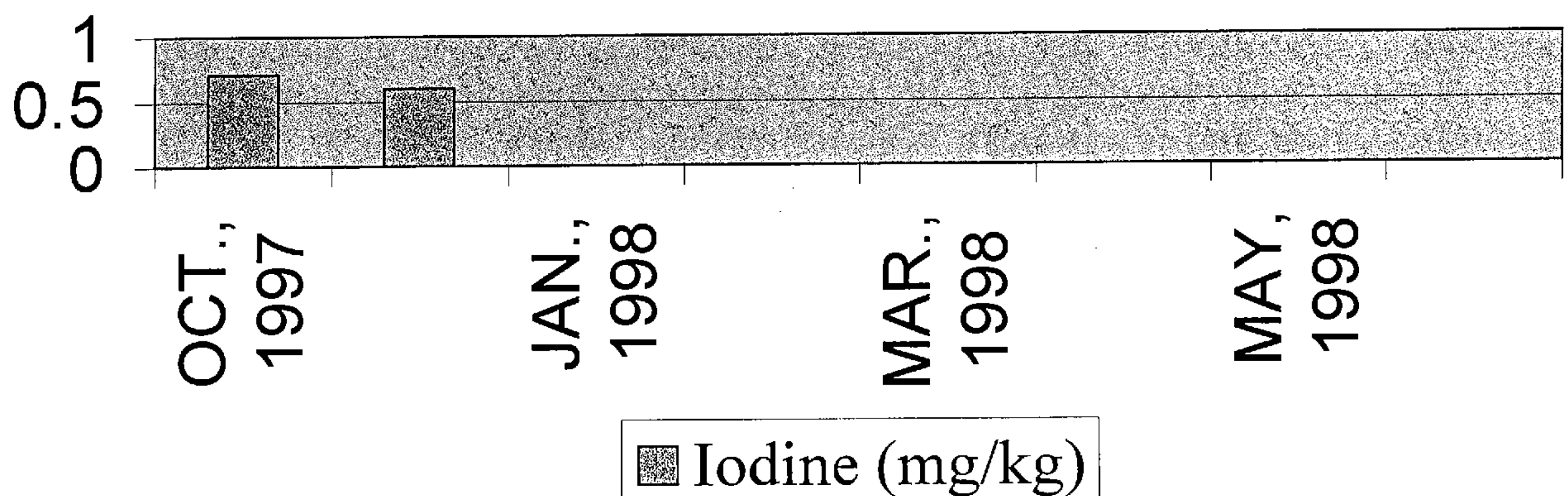


FIGURE (35) INCINERATION FEED ANALYSIS (HAZARDOUS LIQUID)

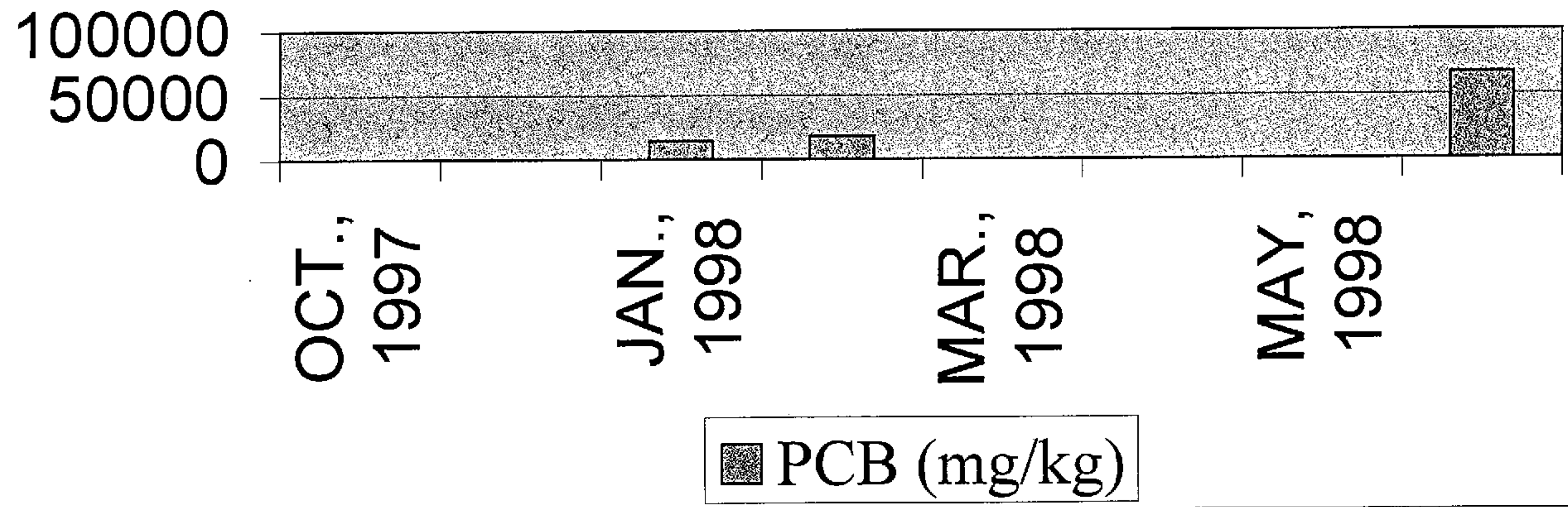


FIGURE (36) INCINERATION FEED ANALYSIS (HAZARDOUS LIQUID)

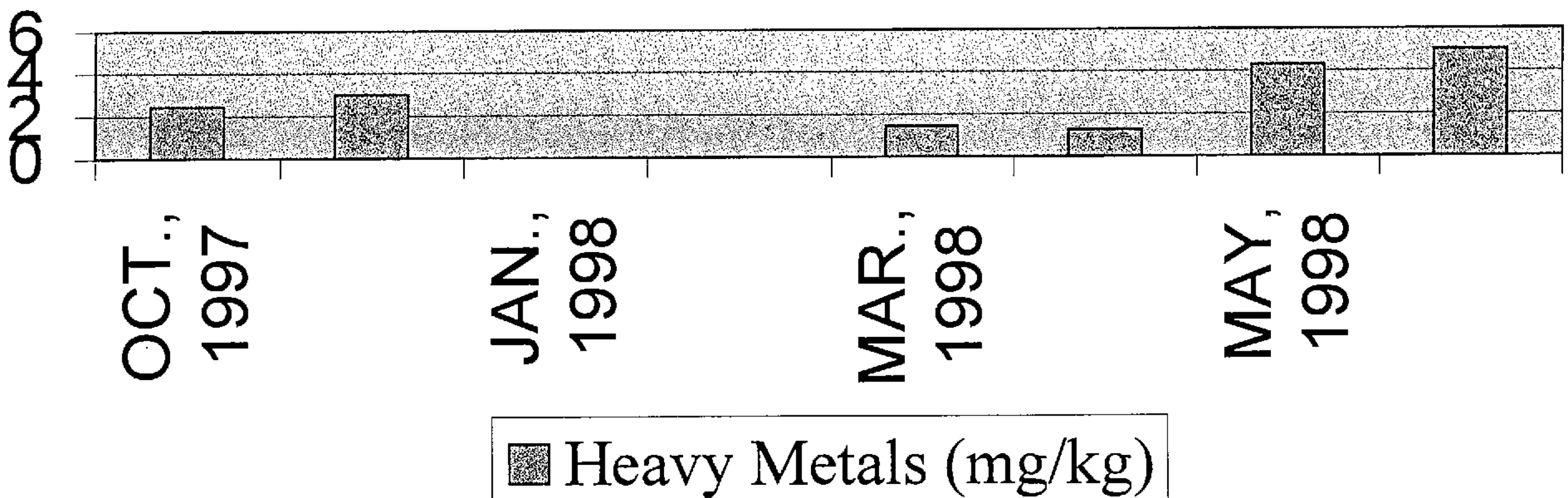


FIGURE (37) ASH SOLIDS ANALYSIS

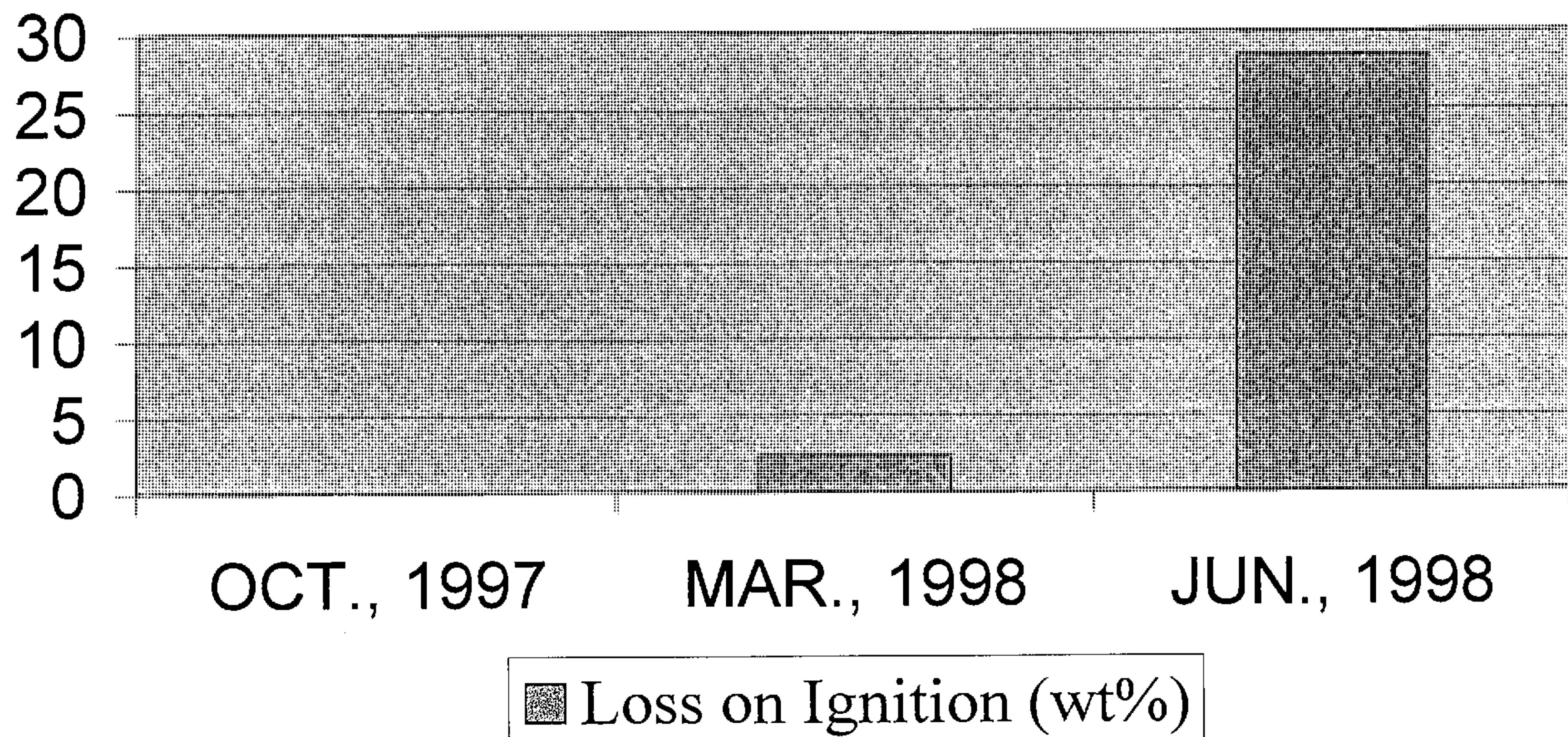


FIGURE (38) ASH SOLIDS ANALYSIS

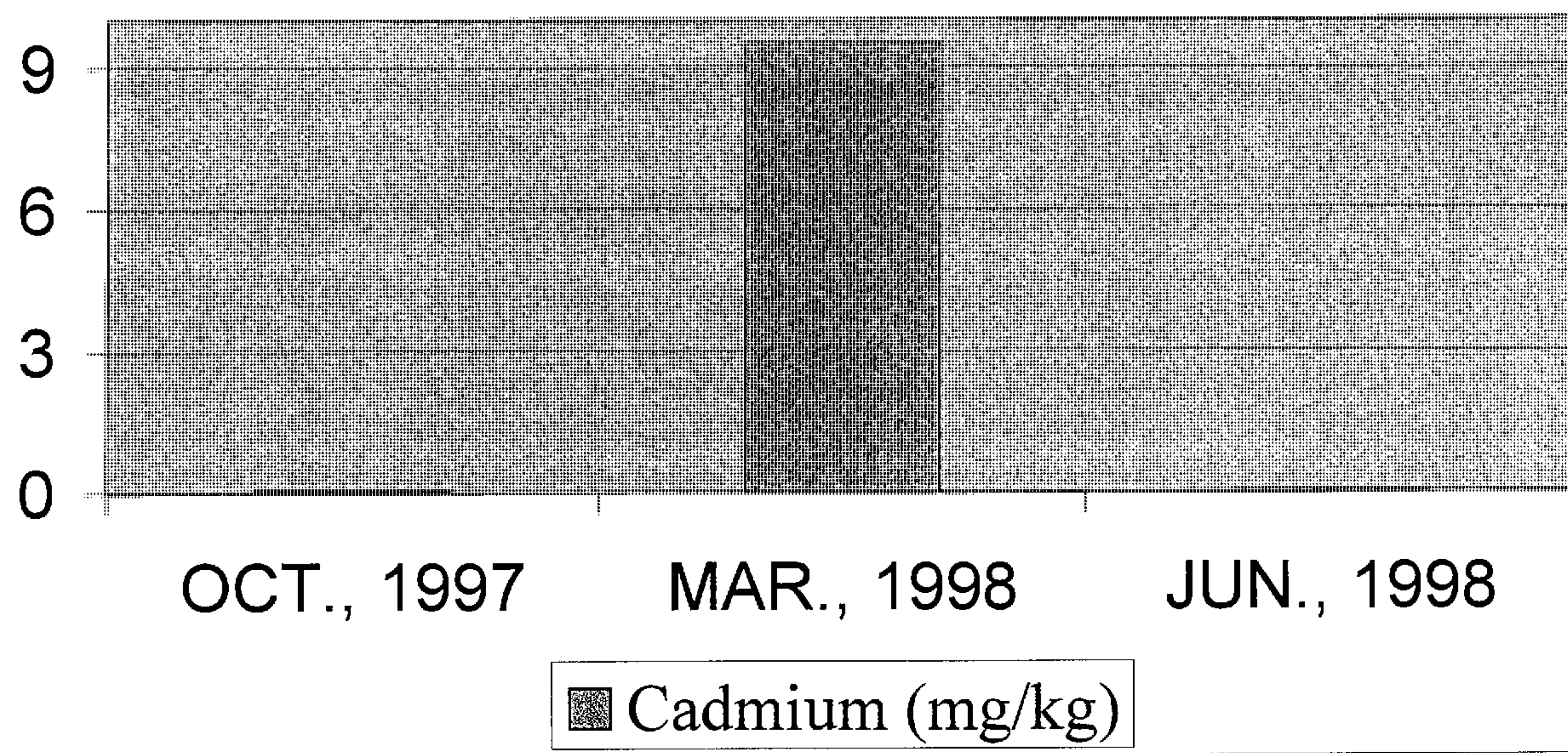


FIGURE (39) ASH SOLIDS ANALYSIS

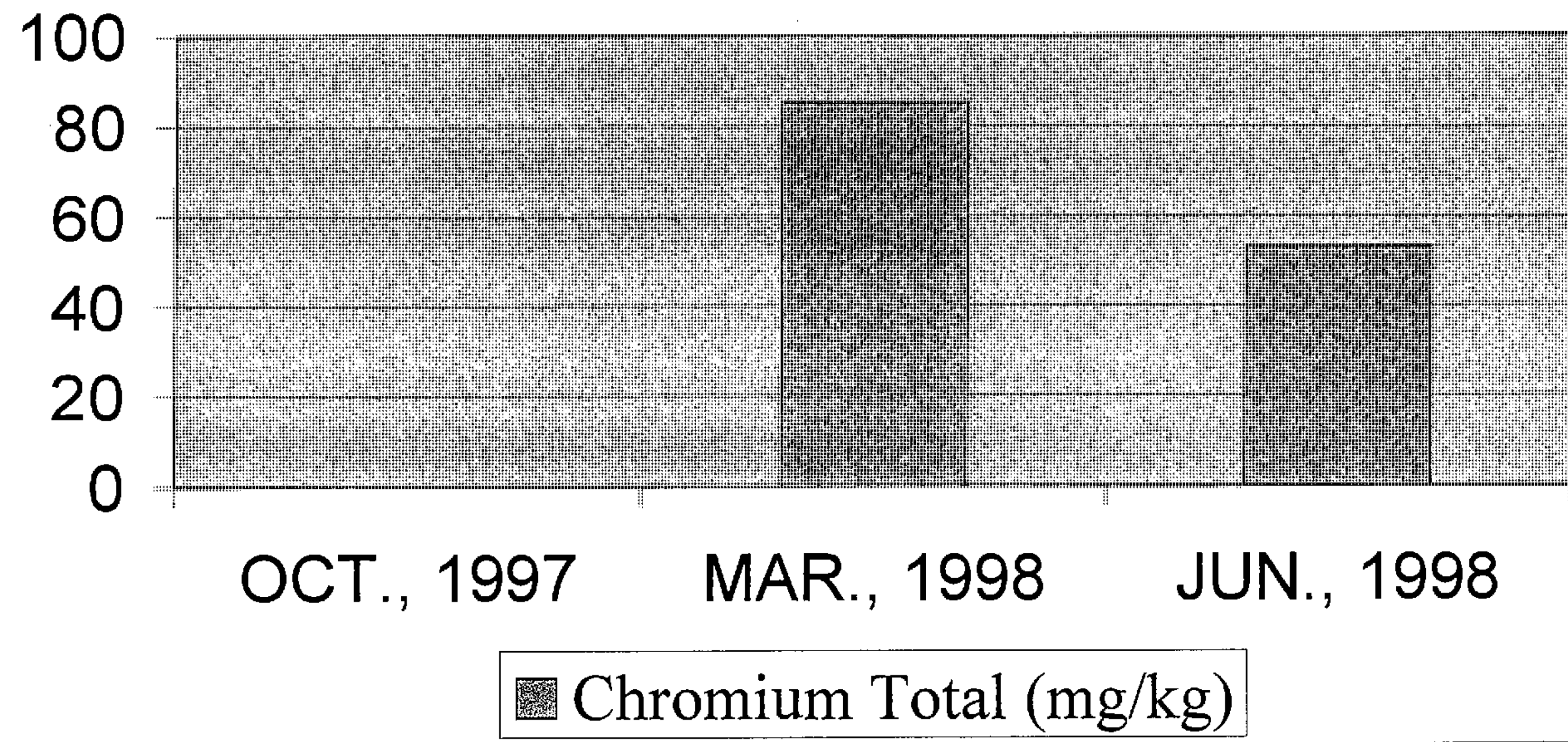


FIGURE (40) ASH SOLIDS ANALYSIS

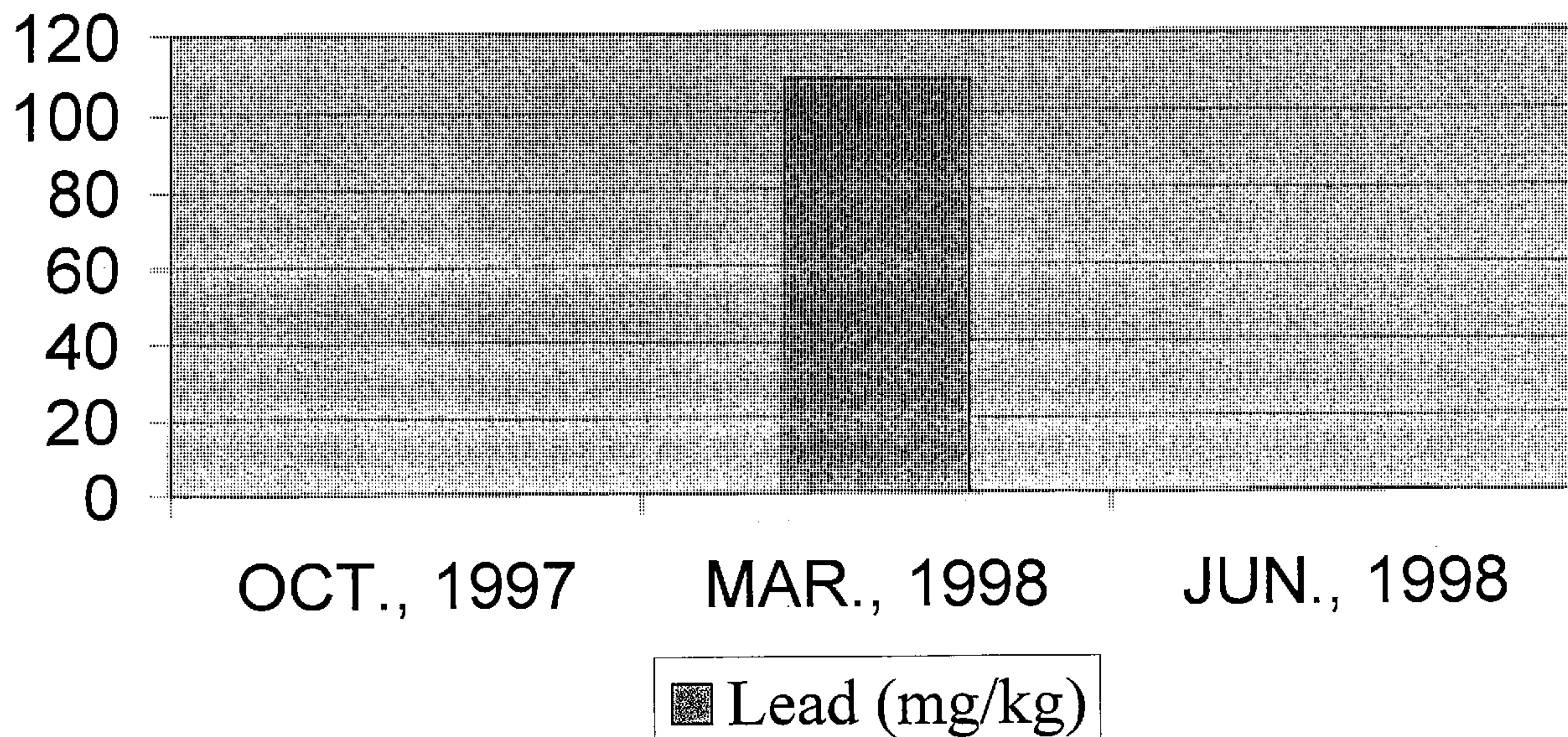


FIGURE (41) STACK EMISSIONS (GAS CONCENTRATIONS)

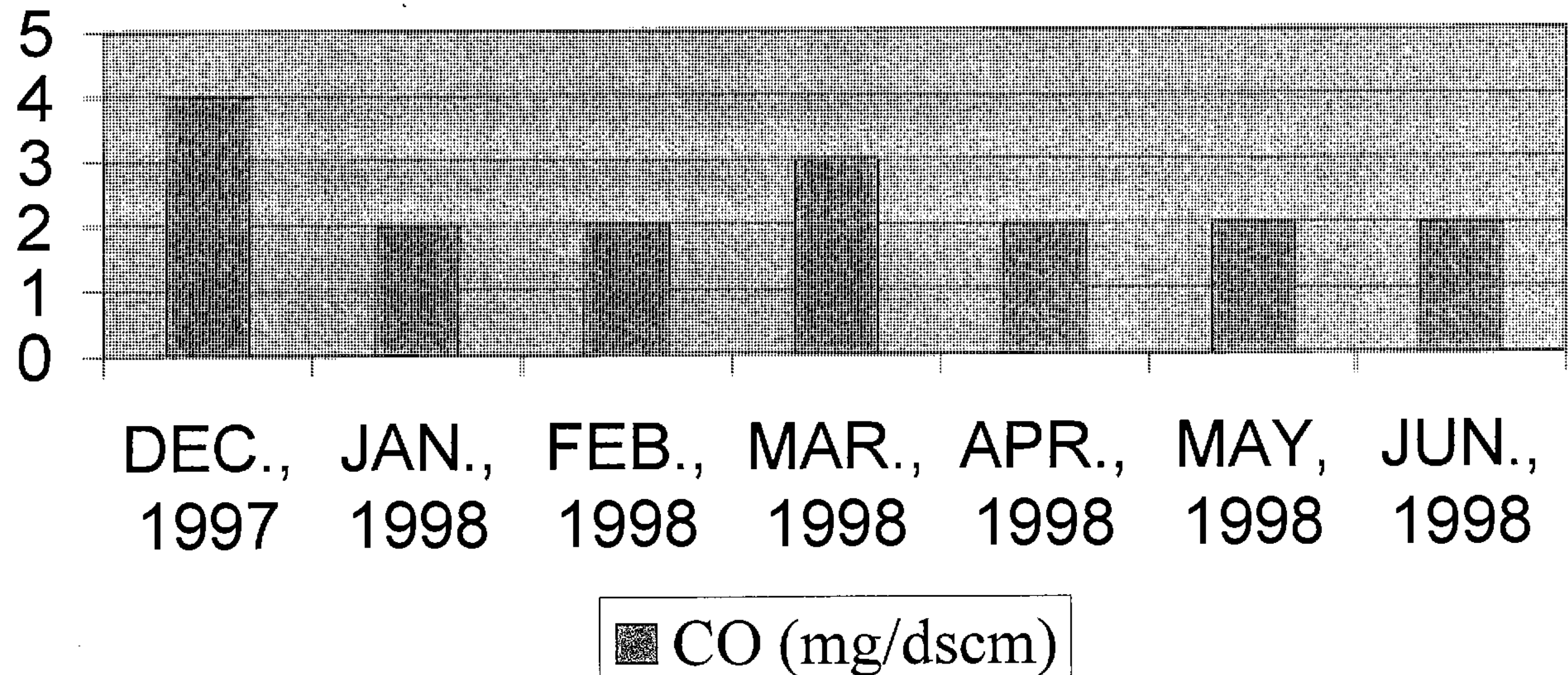


FIGURE (42) STACK EMISSIONS (GAS CONCENTRATIONS)

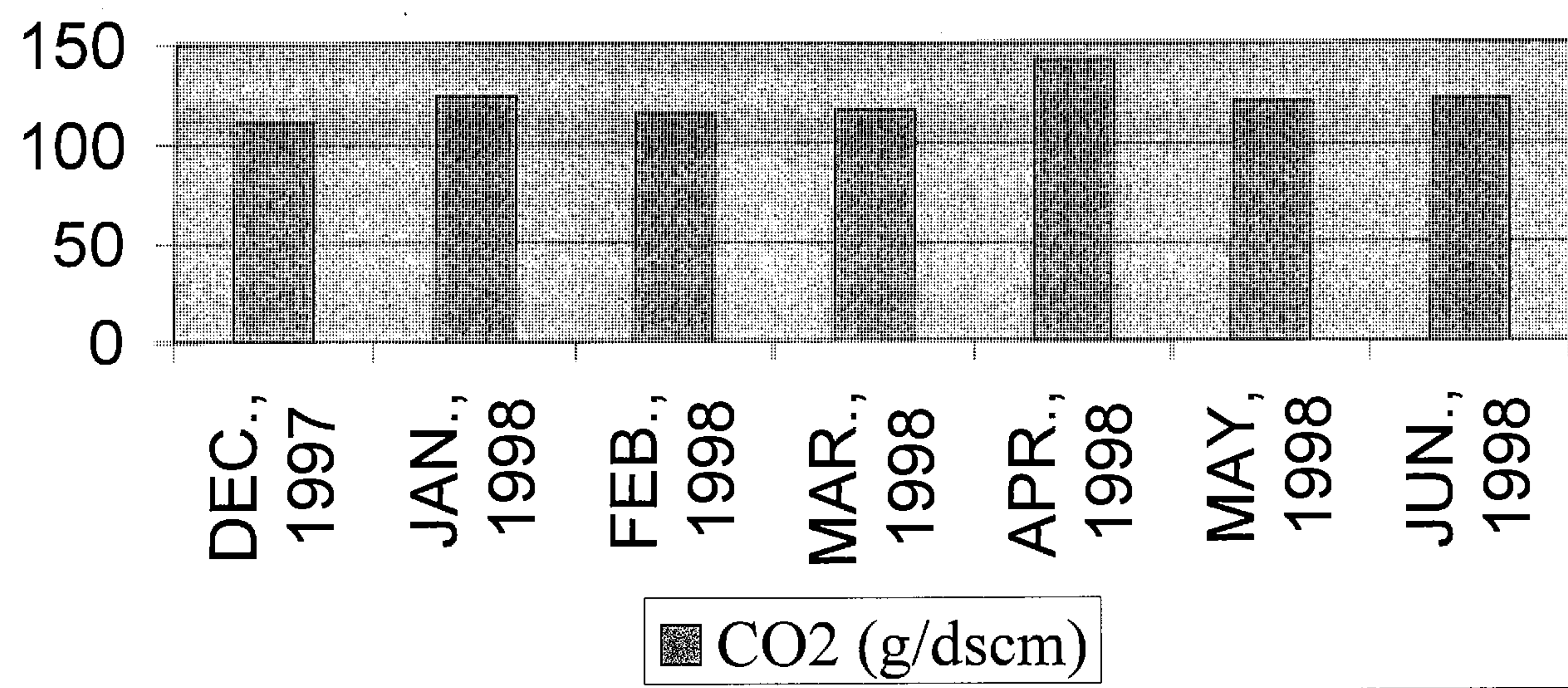


FIGURE (43) STACK EMISSIONS
(GAS CONCENTRATIONS)

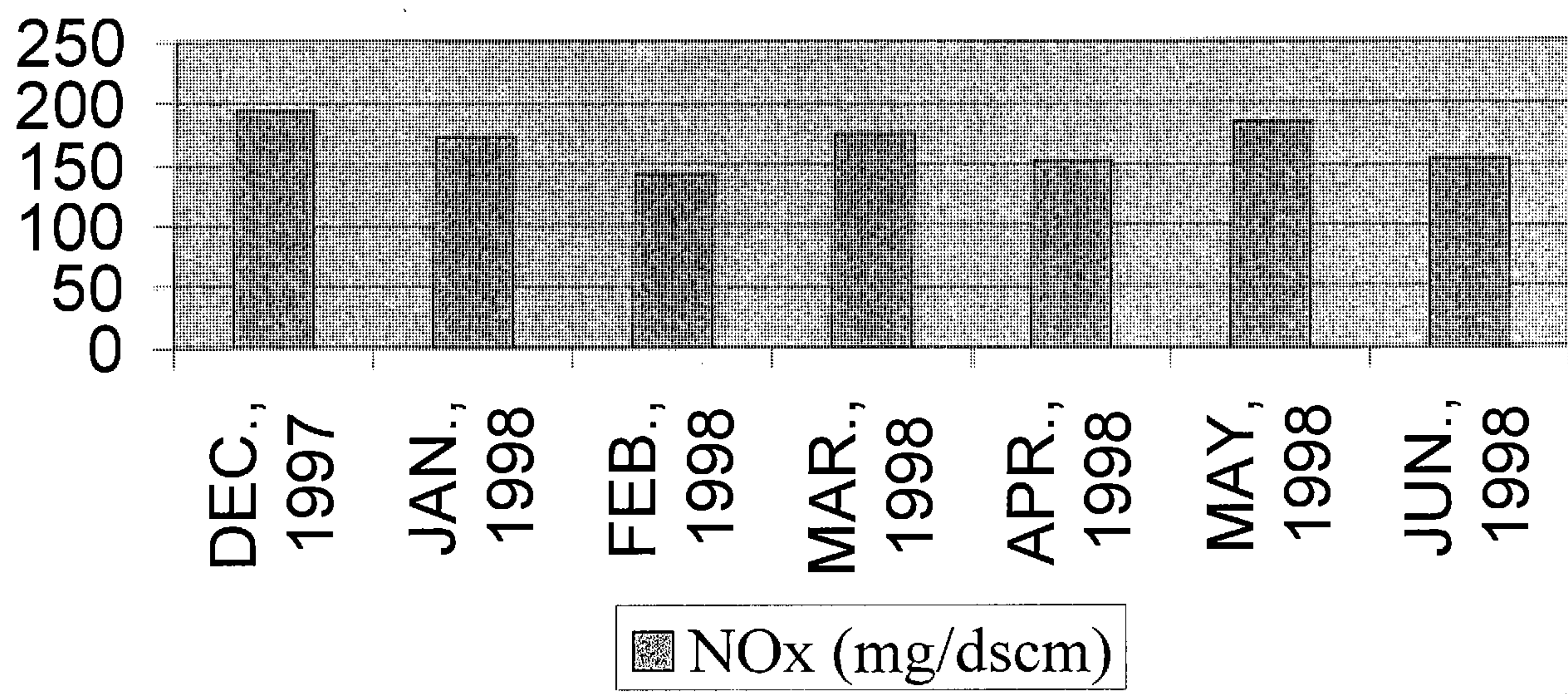


FIGURE (44) STACK EMISSIONS (GAS CONCENTRATIONS)

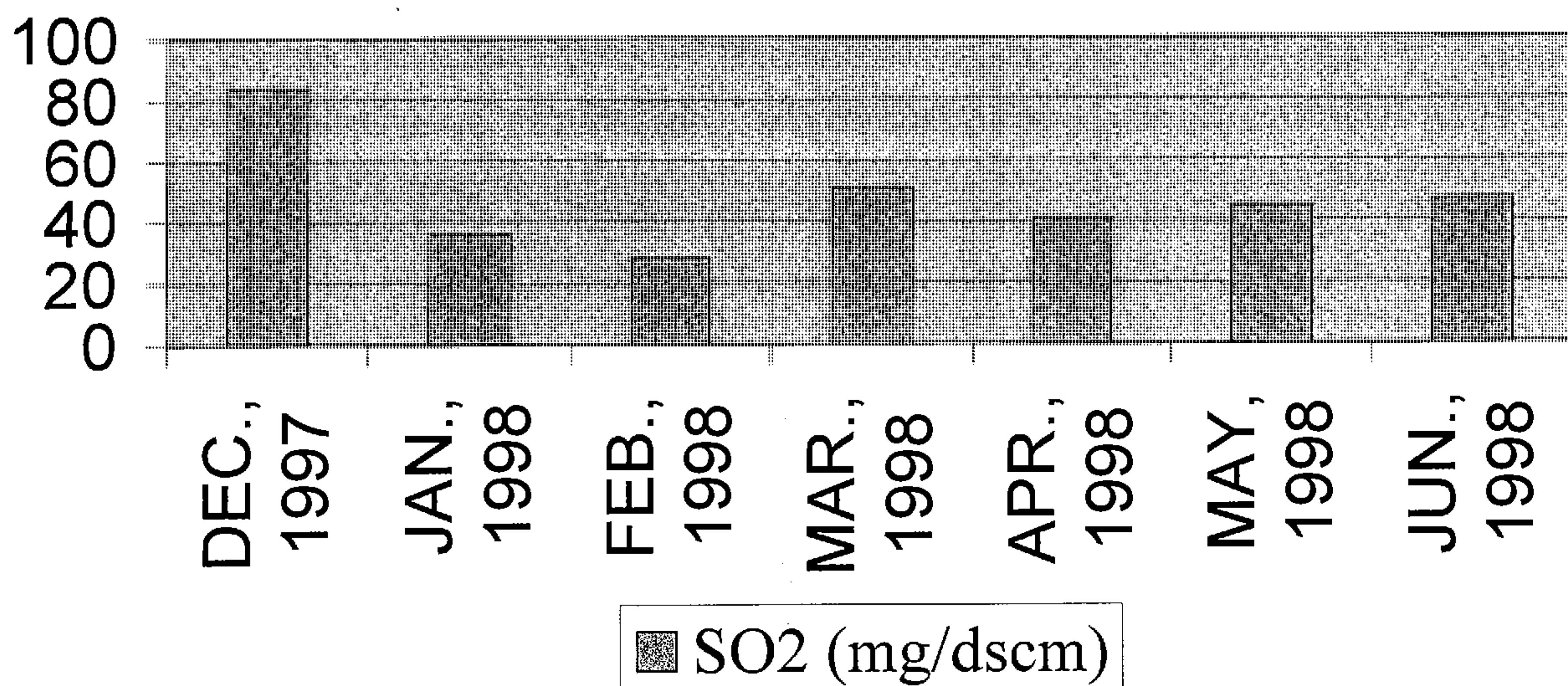


FIGURE (45) STACK EMISSIONS (GAS CONCENTRATIONS)

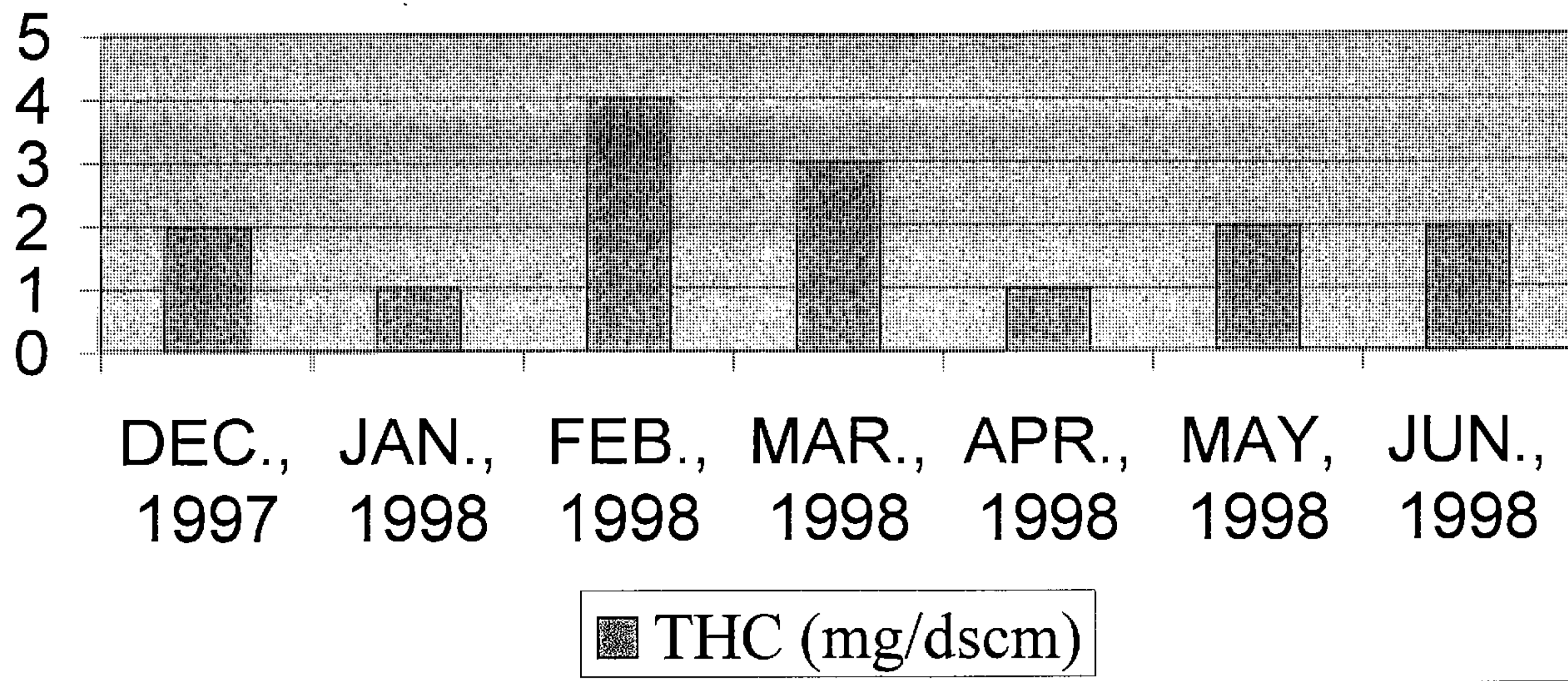


FIGURE (46) STACK EMISSIONS (GAS CONCENTRATIONS)

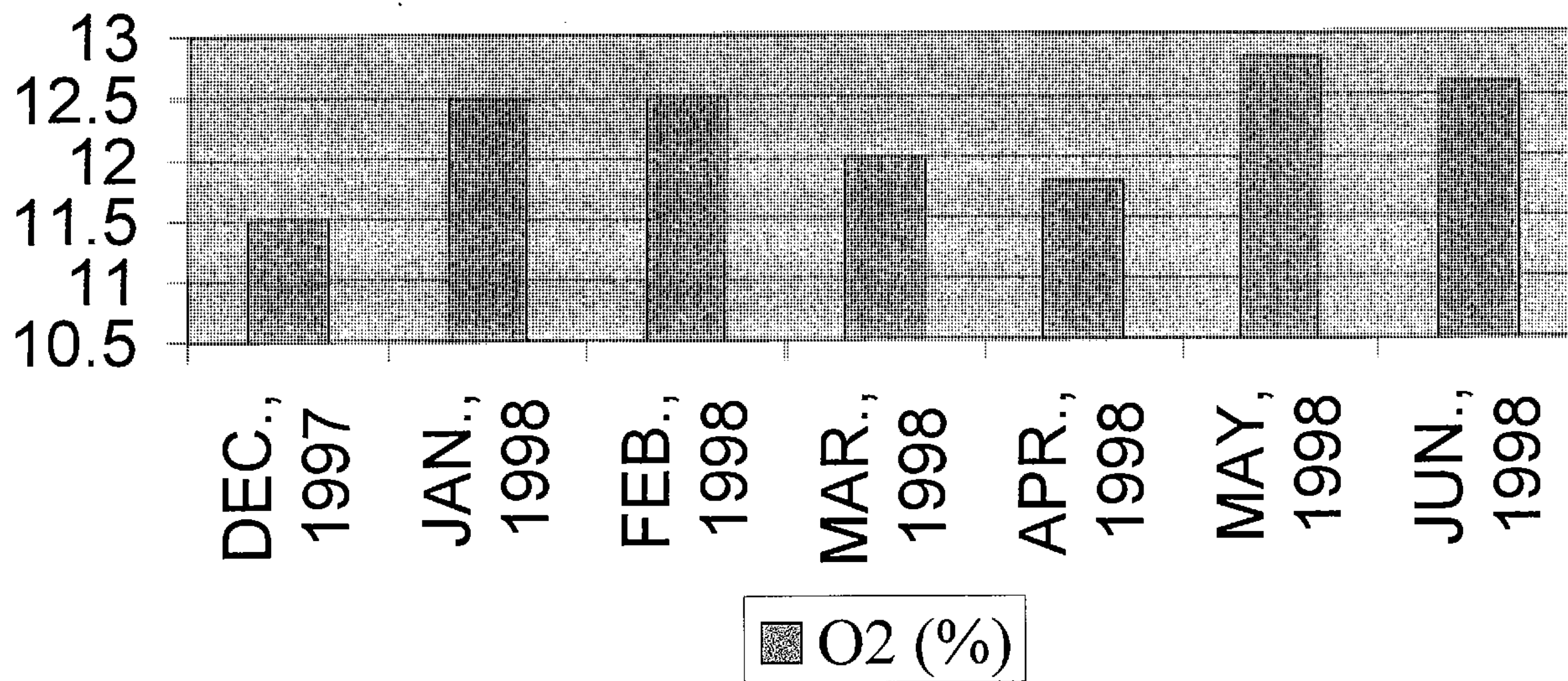


FIGURE (47) STACK EMISSIONS
(GAS CONCENTRATIONS)

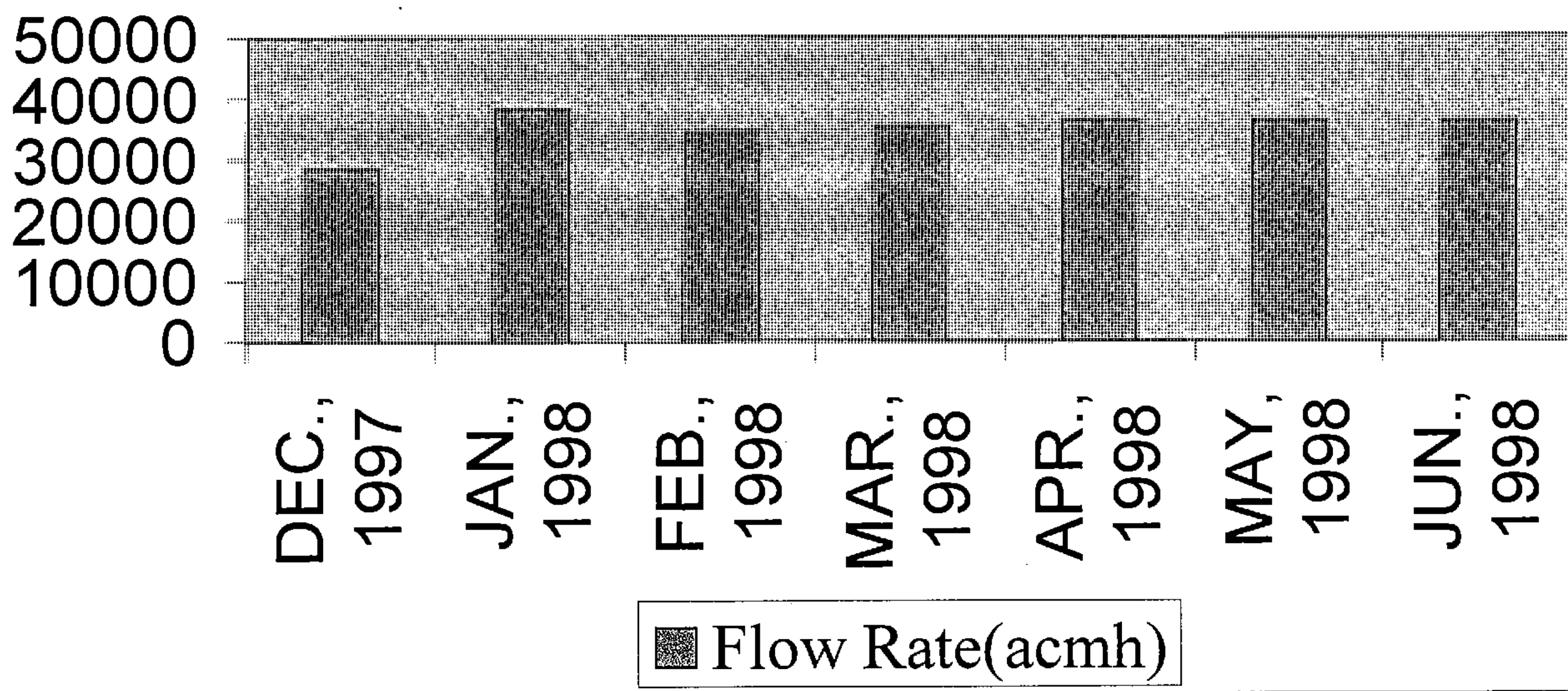


FIGURE (48) STACK EMISSIONS (EMISSIONS RATE)

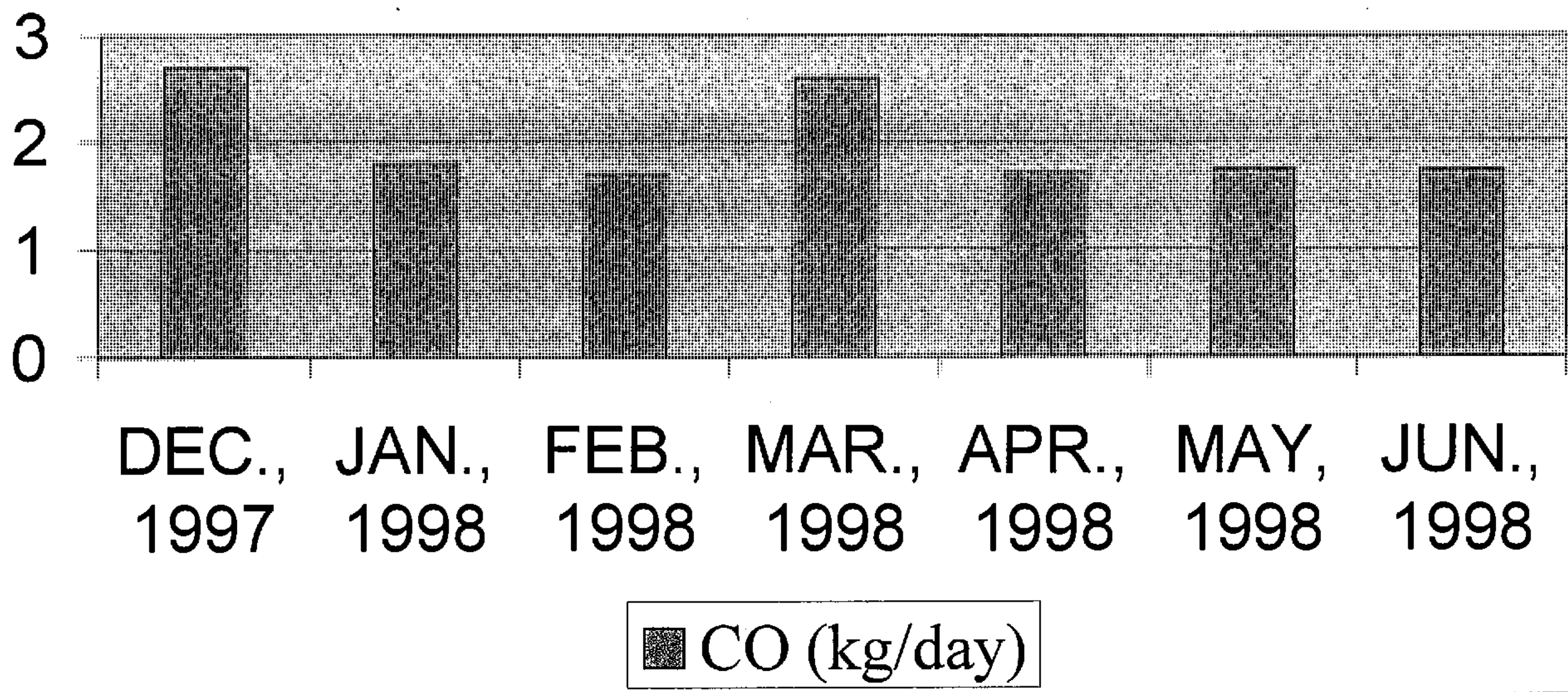


FIGURE (49) STACK EMISSIONS (EMISSIONS RATE)

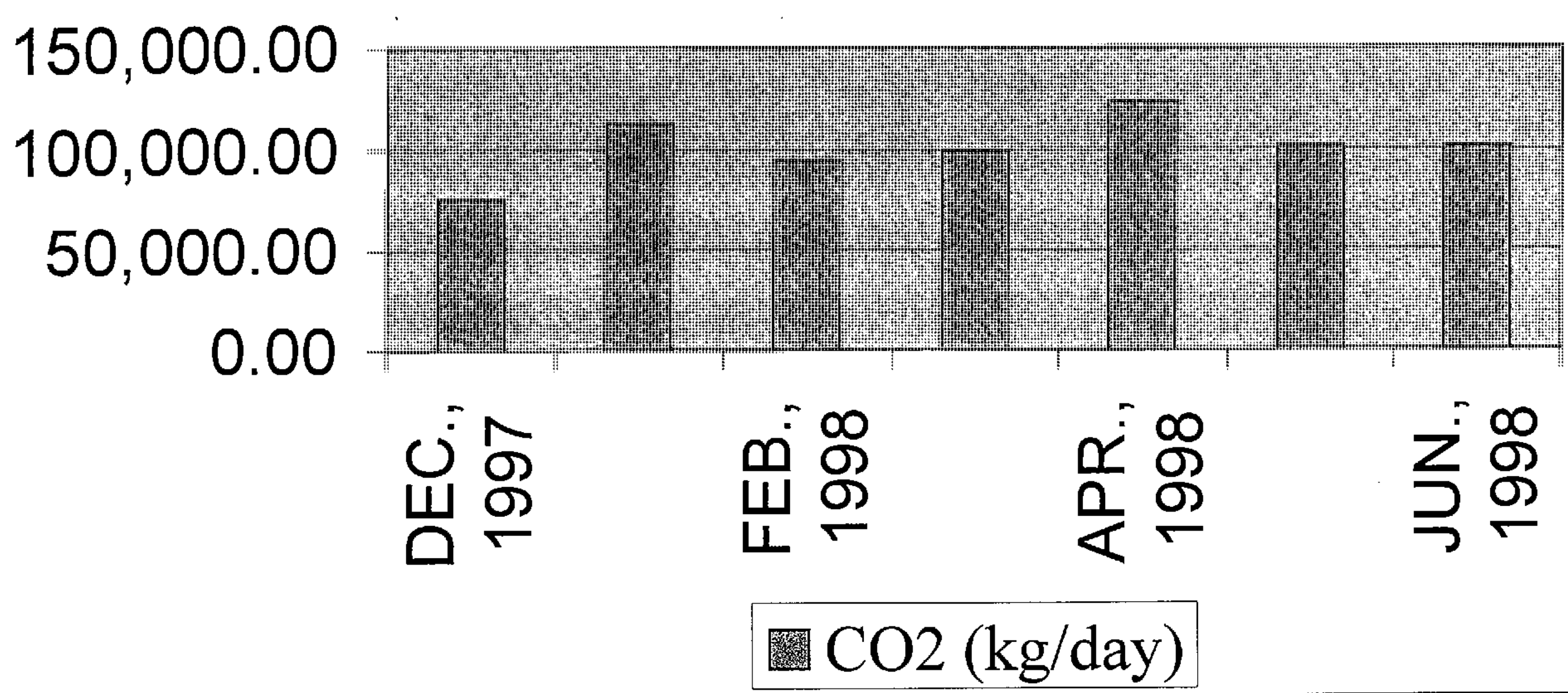


FIGURE (50) STACK EMISSIONS
(EMISSIONS RATE)

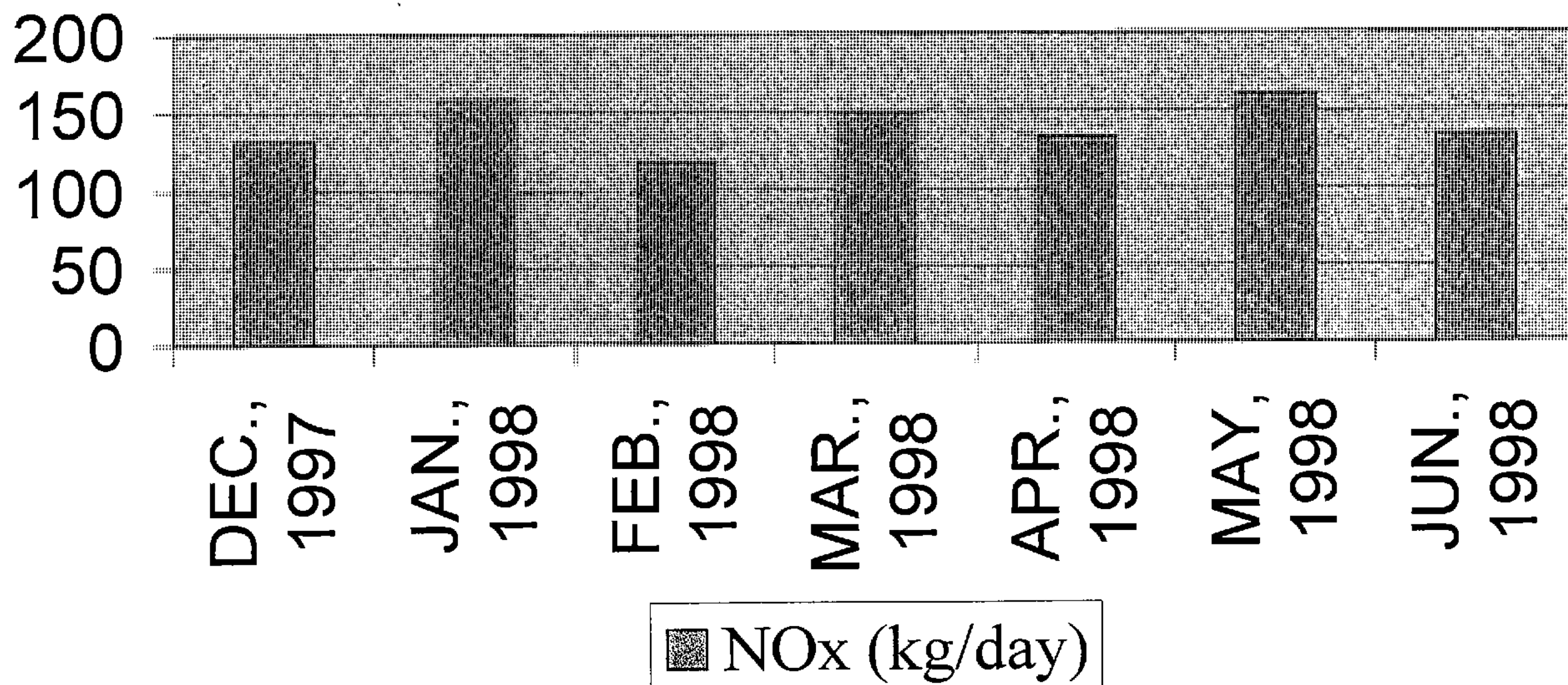


FIGURE (51) STACK EMISSIONS
(EMISSIONS RATE)

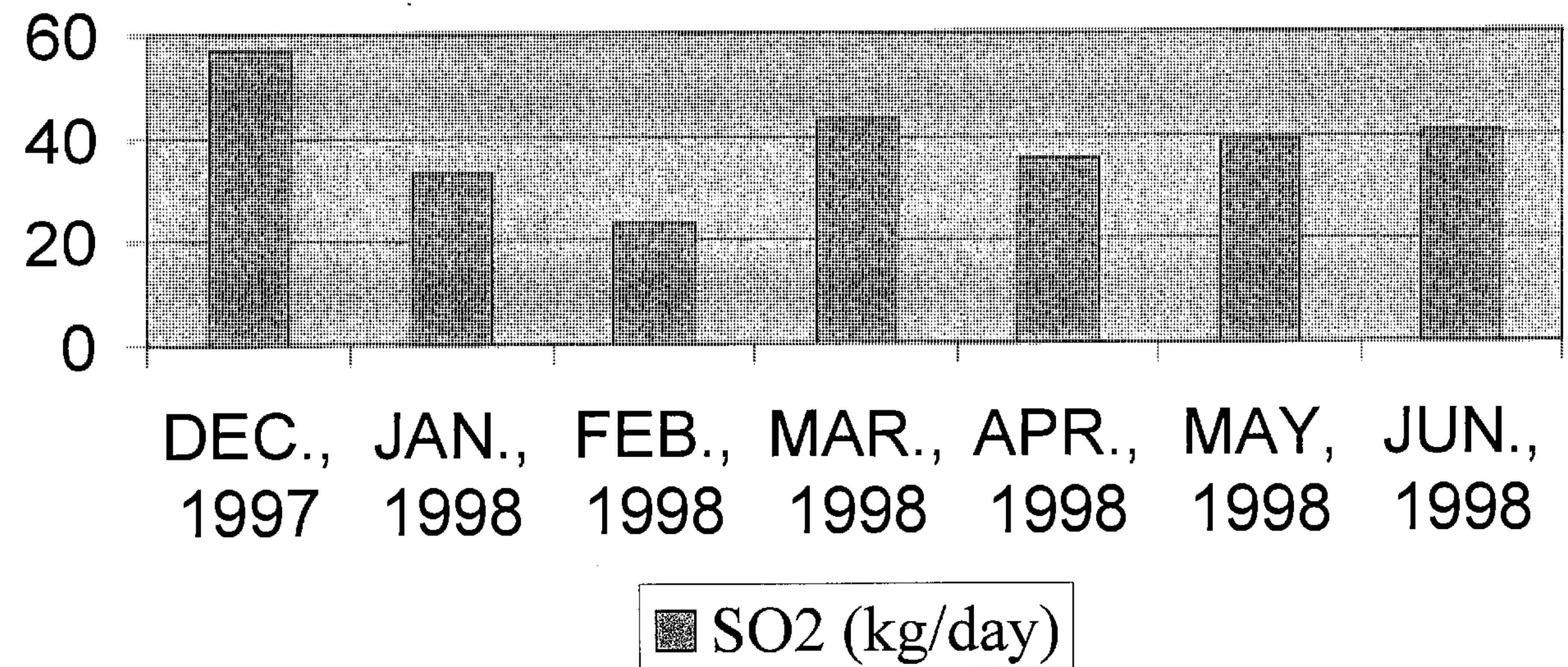


FIGURE (52) STACK EMISSIONS
(EMISSIONS RATE)

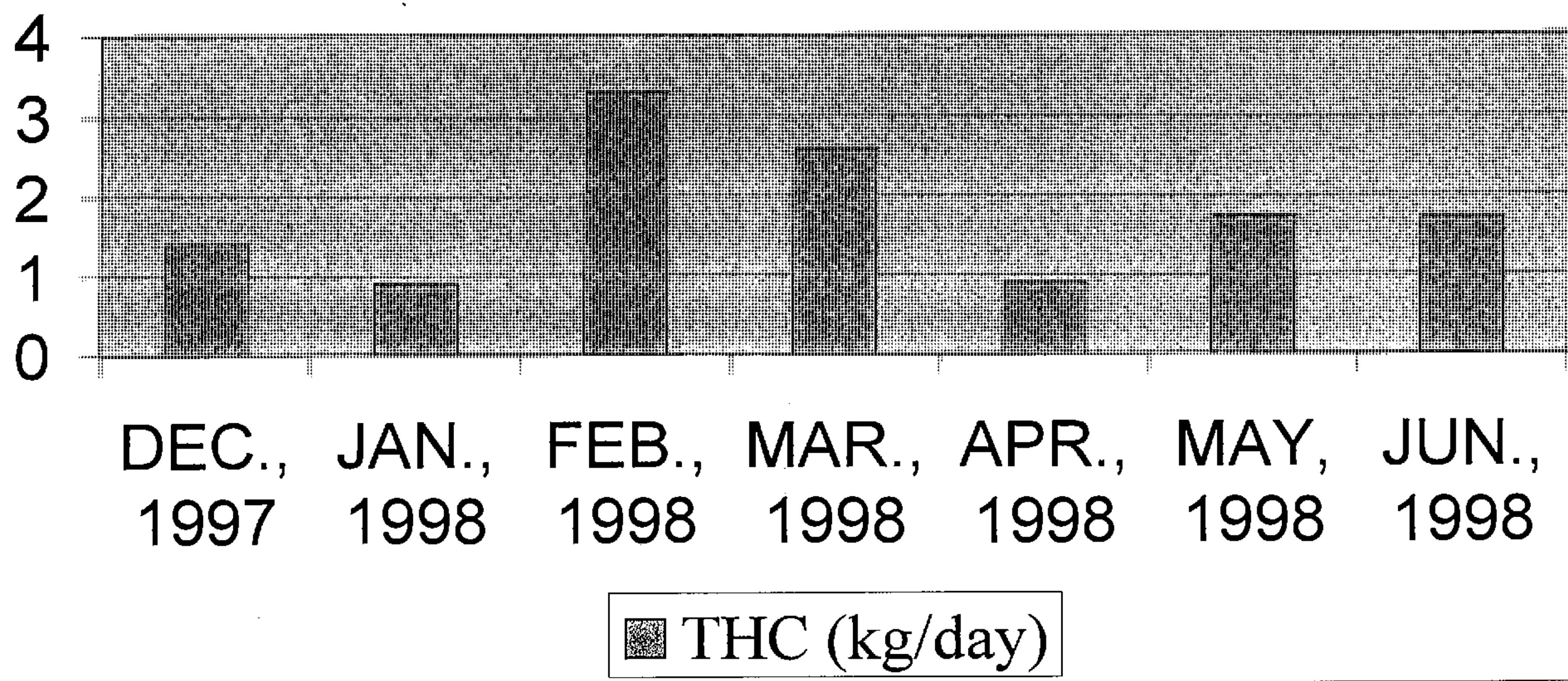


FIGURE (53) STACK EMISSIONS (EMISSIONS RATE)

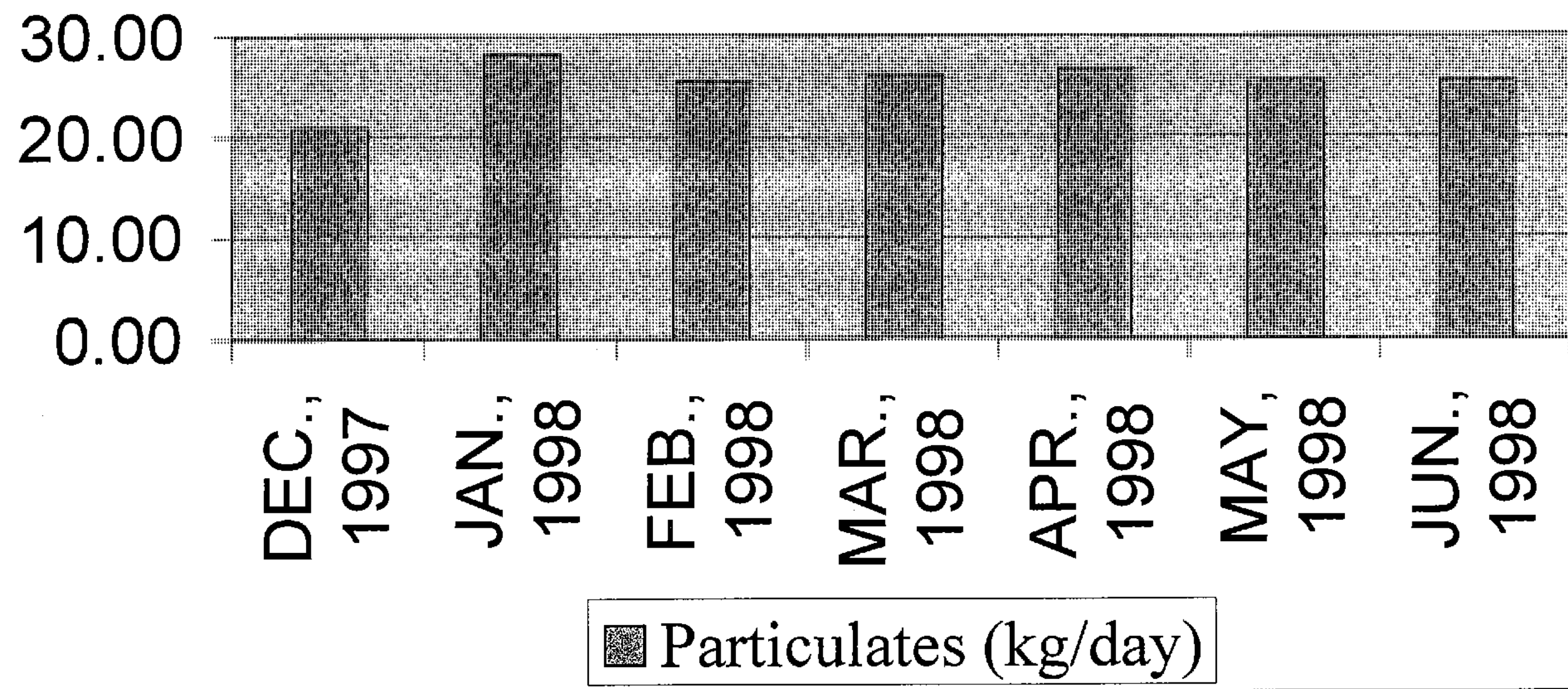
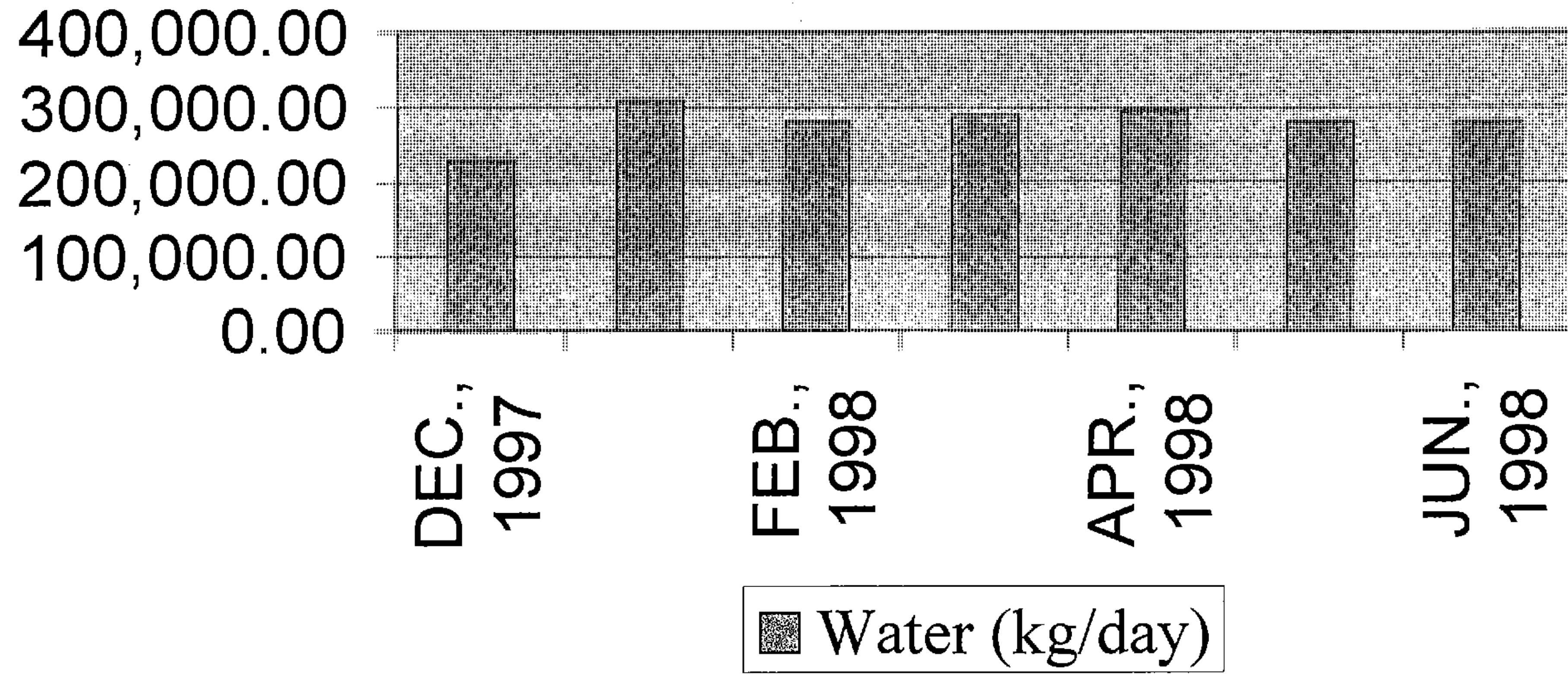


FIGURE (54) STACK EMISSIONS (EMISSIONS RATE)



A special study was performed for the subject incinerator, which a one sample was collected from the waste feed before incineration, and one sample of the ash material after incineration was also collected for a one-time analysis. This is in order to, analyze for selective chemical and physical analysis parameters. Results in table (18) showed some change in some parameters such as; pH, Loss on Ignition, Moisture Content, Chloride, Potassium, Silica, Sodium, Sulfur, Arsenic, Mercury, and Zinc.

There are a number of assumptions that should be made to expedite the material balance calculation of incinerator system. All hydrogen present converts to water vapor (H2O), all chlorides convert to Hydrogen Chloride (HCl), all carbon converts to Carbon Dioxide (CO2), all sulfur present converts to Sulfur Dioxide (SO2), all nitrogen will take the form as (NO), and so on (Brunner 1989). The special sample that was collected on 22 December 1999 from BeeA'h incinerator was used to conduct the material balance.

Calculation of Combustion Products from Waste Feed (Material Balance):

In order to complete this, we have to calculate combustion products from the waste feed.

So, The waste feed rate on the day of sample collection = 10366 kg/day

Then, we have to calculate the water of the waste feed.

Moisture content of the waste feed was 21.6% (table no. 18), so,

H_2O from waste feed = 10366 x 0.216 = 2239 kg H_2O/day

Dry waste feed = 10366 - 2239 = 8127 kg/day

Ash content of the waste feed was 31.3% (table no. 18), so,

Ash material = 8127 x 0.313 = 2544 kg/day

Then, we have to subtract the amount of ash material from the dry waste feed to calculate the combustible compounds remaining without ash material.

Combustible compounds remaining without ash = 8127 - 2544 = 5583 kg/day

Then, we will calculate the combustion products from this combustible compounds remaining without ash as follows; using the Stoichiometric oxygen requirements and combustion products yields factors in table (21) (Crumpler and Martin 1982).

Table (21): Stoichiometric Oxygen Requirements and Combustion Products Yields Factors (Crumpler and Martin 1982).

ELEMENTAL WASTE COMPONENT	STOICHIOMETRIC OXYGEN REQUIREMENTS	COMBUSTION PRODUCTS YIELDS
C	2.67 lb/lb C	3.67 lb CO_2/lb C
Cl_2	- 0.23 lb/lb Cl_2	1.03 lb HCl/lb Cl_2
S	1.00 lb/lb S	2.00 lb SO_2/lb S
Air N_2	—	3.31 lb N_2/lb $(O_2)_{Stoich}$

Loss on Ignition of the waste feed was 4.16% (table no. 18) and we will consider this value as all carbon, so,

CO_2 formed from waste combustion = 5583 x 0.0416 = 232 kg C/day

= 232 kg C x 3.67 kg CO_2/kg C

= 852 kg CO_2/day

Chloride content of the waste feed was 2.14% (table no. 18), so,

HCl formed from waste combustion = 5583 x 0.0214 = 119 kg Cl/day

= 119 kg Cl x 1.03 kg HCl/kg Cl

= 123 kg HCl/day

Moisture content of the waste feed was 21.6% (table no. 18), so,

H_2O formed from waste combustion = 10366 x 0.216 = 2239 kg H_2O/day

SO_3 content of the waste feed was 42.3% (table no. 18), so,

For sulfur (S), we have to calculate the sulfur from SO_3, so,

0.423 x 32/80 = 0.17 S

SO_2 formed from waste combustion = 5583 x 0.17 = 949 kg S/day

= 949 kg S x 2 kg SO_2/kg S

= 1898 kg SO_2/day

Then, we have to calculate the Stoichiometric air required as follows (table no. 21):

O_2 used for Carbon = 232 kg C x 2.67 kg O_2/kg C = 620 kg O_2

O_2 used for Sulfur = 949 kg S x 1 kg O_2/kg S = 949 kg O_2

Total O_2 required = 620 + 949 = 1569 kg O_2/day

N_2 required = 1569 kg O_2/day x 3.31 kg N_2/kg O_2 = 5193 kg N_2/day

Calculation of Combustion Products from Diesel (Material Balance):

In order to complete this, we have to calculate combustion products from the diesel fuel that used in the incinerator. We have that diesel contain 85% of carbon and 15% of hydrogen on weight basis.

So, The diesel fuel feed rate on the day of sample collection = 8000 kg/day

Then, we have to calculate the combustion products from the diesel fuel as follows:

C formed from diesel fuel = 8000 kg/day x 85/100 = 6800 kg C/day

CO_2 formed from diesel fuel = 6800 kg/day x 44/12 = 24933 kg CO_2/day

H_2 formed from diesel fuel = 8000 kg/day x 15/100 = 1200 kg H_2/day

H_2O formed from diesel fuel = 1200 kg/day x 18/2 = 10800 kg H_2O/day

S formed from diesel fuel = 8000 kg/day x 1/100 = 80 kg S/day

SO_2 formed from diesel fuel = 80 kg S/day x 2 kg SO_2/kg S = 160 kg SO_2/day

Then, we have to calculate the Stoichiometric air required as follows (table no. 21):

O_2 used for CO_2 = 24933 kg CO_2/day x 32/44 = 18133 kg O_2/day

O_2 used for H_2O = 10800 kg H_2O/day x 16/18 = 9600 kg O_2/day

O_2 used for SO_2 = 160 kg SO_2 x 32/64 = 80 kg O_2/day

Total O_2 = 18133 + 9600 + 80 = 27813 kg O_2/day

N_2 required = 27813 kg. O_2/day x 3.31 kg N_2/kg O_2 = 92061 kg N_2/day

The above calculations are summarized in table (22) and the material balance is presented in figure (55).

Table (22): Summary of Material Balance Calculation.

	FROM WASTE FEED (kg/day)	FROM DIESEL FUEL (kg/day)	TOTAL (kg/day)
CO_2	852	24933	25785
HCl	123		123
H_2O	2239	10800	13039
SO_2	1898	160	2058

Note:
O_2 (excess) = Total O_2 used in waste feed + Total O_2 used in diesel fuel x 12/100
O_2 (excess) = 1569 kg O_2/day + 27813 kg O_2/day x 12/100
O_2 (excess) = 3526 kg O_2/day

Total N_2 required = 5193 kg N_2/day + 92061 kg N_2/day x 1.12
Total N_2 required = 108924 kg N_2/day

Total air = Total O_2 used in waste feed + Total O_2 used in diesel fuel + Total N_2 required x 1.12

Total air = 1569 kg O_2/day + 27813 kg O_2/day + 108924 kg N_2/day x 1.12
Total air = 154903 kg/day

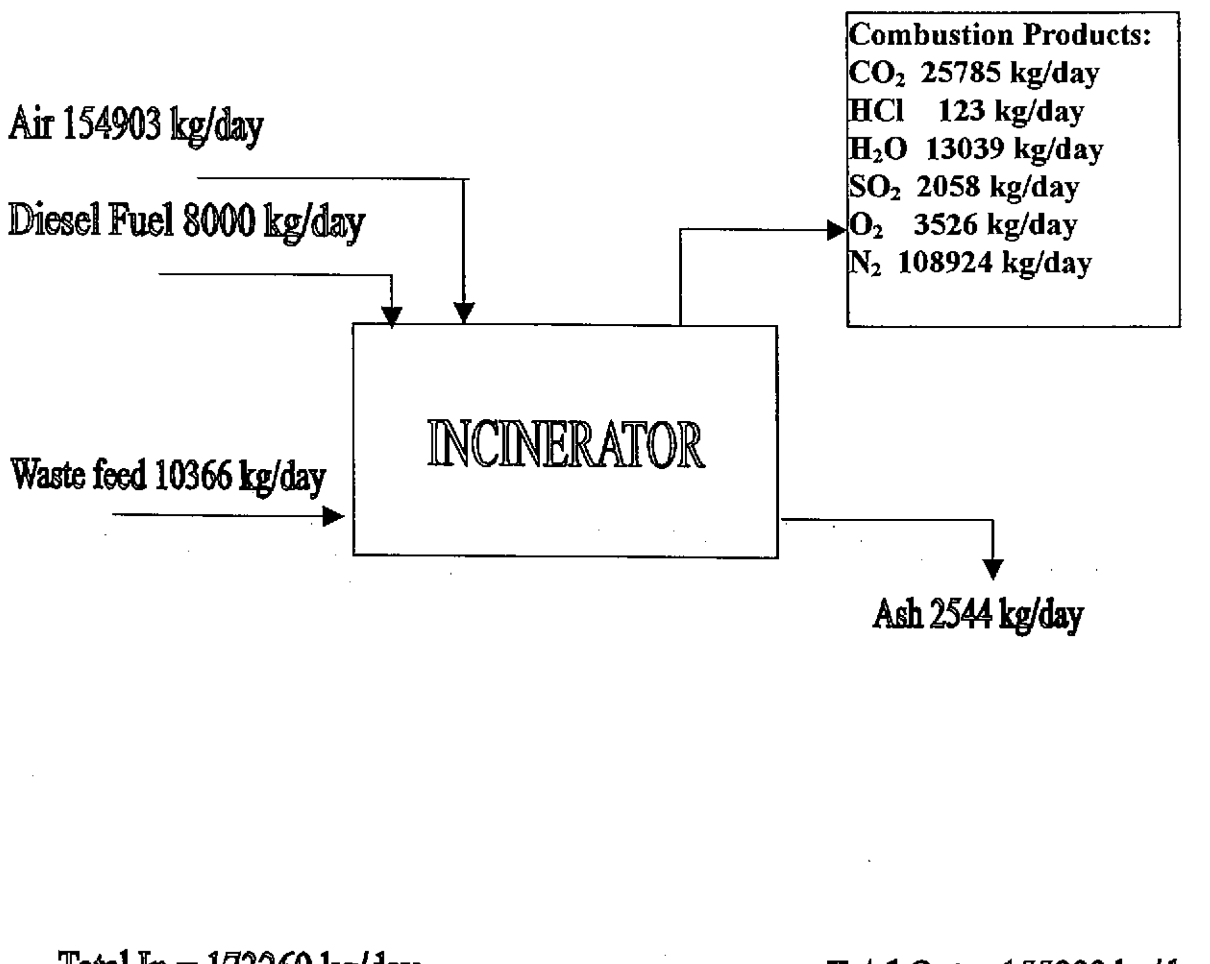


Figure (55): Material Balance Diagram.

5. DISCUSSION

Hazardous waste is a waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment. The % distribution of waste varies from solids, sludge and hazardous liquid and presented in table (5). There were several months that no analysis data were available for several parameters. The reasons for this, that these parameters were not measured by BeeA'h company due to previous information or data that BeeA'h company has of the waste characteristics from the wastes generators.

The monthly average data of waste feed (either solids, sludge, or hazardous liquid) that were presented in tables (6), (7) & (8) were based on the BeeA'h log sheets that recorded for each month for selective days of analysis (the average of selective days of analysis for these log sheets). There were several months that no analysis data were available for several parameters. As mentioned previously, the reasons for this, that these parameters such as; Phosphorus, Bromine, Chlorine, Fluorine and Iodine were not measured by BeeA'h company due to previous information or data that BeeA'h company has of the waste characteristics from the wastes generators.

The monthly average data of the residues/ash material that were presented in tables (9) are being disposed of in BeeA'h landfill. This is according to the standards and regulations. There were several months that no analysis data were available for several parameters. The reasons for this that these parameters were not measured by BeeA'h Company due to their practices of accumulation the residues/ash for several months. For instances, data for the months of November, 1997, December 1997, January

1998, and February 1998 were accumulated and measured in March 1998 and so on.

The results of the Arsenic, Cadmium, Chromium, Lead, and Mercury parameters that were analyzed by the Toxicity Characteristic Leaching Procedure (TCLP) method of the residues/ash were compared with some of the Toxicity Characteristic Leaching Procedure (TCLP) regulatory levels in table (11) in order to, identify any violations.

When hazardous waste is disposed of in a land disposal unit, toxic compounds or elements can leach into underground drinking water supplies and expose users of the water to hazardous chemicals and constituents. In order to, reduce the possibility of migration of these wastes to ground water, and surface water so to protect human health and the environment; EPA developed the Toxicity Characteristic (TC) to identify wastes likely to leach dangerous concentrations of toxic chemicals into ground water (USEPA 1998).

Comparison of the monthly average results (October 1997-June 1998) between ash solids and some of TCLP regulatory levels showed that increase in Cadmium parameter in the month of March, 1998, Chromium parameter in both months March and June, 1998, and Lead parameter in the month of March, 1998, however; Arsenic and Mercury were below the regulatory levels. This lead that, the ash solids need to be further treated prior to direct disposal in BeeA'h landfill.

A study by a team of engineers at Rutgers, the state university of New Jersey, shows that municipal incinerator ash is more dangerous than previously realized. Chemical engineers at Rutgers have released a new

study showing that toxic metals in municipal incinerator ash are more abundant and more soluble, and therefore more dangerous, than previously thought. The Rutgers team took samples of household solid waste from three locations (Pennsauken, NJ, Magnolia, NJ, and Somerset County, NJ) and burned them in a small (50 ton per day) solid waste incinerator. The types of ash contain toxic heavy metals (Chromium, Cadmium, Lead, Arsenic, Zinc, and other metals) as well as organic compounds. They captured the fly ash and the bottom ash. The actual composition of the metals in the ash that resulting from combustion of household wastes is described as follows; Arsenic is 100 ppm, Cadmium is 37 ppm, Chromium is 49 ppm and Lead is 2824 ppm. As is obvious from these numbers (which are all given as parts per million, or ppm) there are large quantities of metals in the ash. Several lessons learned from the work at Rutgers; first, the amount of metal in solid waste ash varies from place to place with socio-economic status, geographic location, season, collection patterns, and recycling practices. The waste stream should be sampled frequently to see what it really contains. Second, the quantity of toxic metals in the waste may be very high and the toxicity will endure forever (Clapp 1988).

A test program was performed at the Environmental Protection Agency's incineration research facility to study the effectiveness of incineration at low-to-moderate temperatures in decontaminating soils containing organic compounds with different volatilities. A related objective was to determine the fate of contaminant metals in the contaminated soil. With the exception of Mercury, the extent of metal volatilization from the treated soil was not significantly affected by any of the test variables. On average, Arsenic, Barium, Cadmium, Chromium and Lead were not volatile and remained in the soil. The effects of thermal treatment on metals leachability in the Toxicity Characteristic Leaching

Procedure (TCLP) vary from metal to metal. Lead and Barium leachabilities were not affected by any of the test variables. Leachable fractions of Arsenic and Cadmium decreased when soil temperature increased. In contrast, leachable fractions of Chromium and Mercury increased when soil temperature increased (USEPA 1997).

A study was conducted for municipal solid waste incinerator residues (Alba, Gasso, Lacorte and Baldasano 1997). In the ashes, the concentrations of Lead and Chromium in leachates were higher than limits established in the European regulation concerning waste disposal. These results imply that these residues should be treated before landfilling.

A specialist hazardous waste incineration sector currently operates with high standards. An exact knowledge of the behaviors of pollutants in the incineration process, such as heavy metals, is of primary importance. The following is a test that was performed at Indaver NV with the specific aim of collecting information concerning this subject. The test was performed in a rotary kiln incinerator, situated in the Port of Antwerp (Belgium). The results indicated that about 99.9% of the pollutants (Mercury, Cadmium, Arsenic, Lead, Copper and Zinc) are concentrated and immobilized in the solid residues. A specialist hazardous waste incinerator has two major goals. First, the destruction of the organic fraction of the waste with a minimal effect on the environment. Second, the concentration and immobilization of inorganic pollutants, such as heavy metals, in the solid residues which are then safely disposed of in a landfill; in this way, the dispersion of heavy metals into the environment is prevented and zero emissions in the long term are guaranteed (Guido 1997).

The monthly average data results of 9 months (October 1997-June 1998) of incineration waste feed were compared to the monthly average data results of 9 months (October 1997-June 1998) ash solids after incineration that analyzed through BeeA'h laboratory and were presented in table (12) showed change in Sodium, Sulfur and Chlorine parameters. For Sodium parameter, there was an increase in the value of the ash solids with 172%. For Sulfur parameter, there was a decrease in the value of the ash solids with 79%. For Chlorine parameter, there was a decrease in the value of the ash solids with 75%. These were related to the combustion process of the waste feed and the resulted ash solids, which reduce the amount of content of both Sulfur and Chlorine.

Comparison of average results of nine (9) months (October 1997-June 1998) between Stack Emissions (Gas Concentrations) and air pollution source standards and were presented in table (17) showed that Carbon Monoxide (CO) and Sulfur Dioxide (SO2) parameters were within the standards.

Since no burning device operates at 100 percent efficiency, some of the items end up only partially burned. These are called Products of Incomplete Combustion (PICs). PICs are created when fragments of partially burned materials stabilize or recombine to form new chemicals. A simple type of PIC is CO, and should be a good surrogate for formation of other, more dangerous PICs. Critics' charge that CO monitoring can reveal gross upsets, but does not reveal the production of PICs under optimal conditions. US EPA counters that low CO levels have been demonstrated to indicate that PICs formation is low. The only degree to which CO is a poor surrogate, EPA believes, is that CO may set off false alarms; high CO levels are not always associated with high levels of PICs (Kopel 1993).

In the months of October and November, 1997 there were no data available (not measured) for stack emissions from BeeA'h company records.

Results of the special sample (waste feed and ash) analysis (table (18)) showed some change in some parameters such as; Conductivity, Ash Content, Loss on Ignition, Moisture Content, Chloride, Magnesium, Potassium, Silica, Sodium, Sulfur, Arsenic, Cadmium, Chromium Total, Mercury, and Zinc. Most of the results were related to the combustion process of the waste feed and the resulted ash solids, which either reduce or concentrate the amount of content of these parameters.

Metals are of possible concern in waste incineration because of their presence in many hazardous wastes and because of possible adverse health effects from human exposure to emissions. Incineration may change the form of metal fractions in waste streams, but it will not destroy the elemental metals (Dempsey and Opplet 1993). The principal environmental concern therefore centers around where and in what physical or chemical form the metals exit the combustion system, i.e., bottom ash or stack emissions. Until recently, data on metal behavior in hazardous waste incinerators were quite limited. The focus of most emission assessments had historically been on organic compounds. (Dempsey and Opplet 1993).

The material balance (figure (55)) shows some difference between in and out. The difference could be related to the accuracy of the diesel fuel consumption in the subject incinerator or the analysis of loss of ignition.

The monthly average data results of 9 months (October 1997-June 1998) of incineration waste feed that analyzed through BeeA'h laboratory

were compared to the special sample that collected on 22 December, 1999 of incineration feed and were presented in table (19). Results showed some change in some parameters such as; Ash Content, Sodium and Sulfur. This is in order to, provide an idea and to see the difference in data results of BeeA'h Company.

The monthly average data results of 9 months (October 1997-June 1998) of ash solids after incineration that analyzed through BeeA'h laboratory were compared to the special sample that collected on 22 December, 1999 of ash after incineration and were presented in table (20). Results showed some change in some parameters such as; Loss on Ignition, Calcium, Sodium, Sulfur, Arsenic, Cadmium, Chromium Total, Lead and Mercury. This is in order to, provide an idea and to see the difference in data results of BeeA'h Company.

6. CONCLUSION

The body of knowledge concerning hazardous waste incineration has been expanding rapidly since 1980. A number of conclusions may be drawn on the status of incineration technology, current practice, monitoring methods, emissions and performance, and public health risks. The following conclusions may be drawn:

- Incineration is a demonstrated, commercially available technology for hazardous waste treatment. Considerable design experience exists, and design and operating guidelines are available covering the engineering aspects of these systems. Therefore, incineration (with full control) is one of the acceptable methods that could be used by the industry for waste treatment and disposal.
- A variety of process technologies exist for the ranges of hazardous wastes appropriate for thermal destruction. The most common incinerator designs incorporate one of four major combustion chamber designs: liquid injection, rotary kiln, fixed hearth or fluidized bed. The most common air pollution control system involves combustion gas quenching followed by a Venturi scrubber (for particulate removal), a packed tower absorber (for acid gas removal) and a mist eliminatory. Newer systems have incorporated more efficient air pollution control devices, however, such as wet electrostatic precipitators ionizing wet scrubbers, spray dryer absorbers, fabric falters and proprietary system. These are to provide more air pollution control for the subject incinerators and to produce clean products.
- The technology of stack sampling for trace organic compounds is relatively sophisticated. Considerable

experience and attention to quality assurance and quality control are needed. Documented sampling and analysis methods are available for most of the compounds and parameters of interest in incineration performance assessment.

- Continuous emission monitors are available with adequate operating ranges for many of the combustion emissions of interest (CO, CO_2, O_2, NO_X and opacity). Continuous monitors for specifics organic compounds or, however, is not available.
- Significant progress has been made during the past few years in understanding the fate of heavy metals in incineration systems and the efficiency of special hazardous waste incinerator air pollution control equipment to control emissions of specific metals.
- Overall, data on incinerator ash and air pollution control residues indicate that may be very small amounts of residual organic compounds could remain in the incinerator ash. Thus, the destruction and removal efficiencies reported for incinerators are almost entirely the result of destruction, rather than removal, of organic compounds. This suggests that some fraction of the residuals generated by the incineration of hazardous wastes, which are subject to the land disposal standards, may require further treatment (such as stabilization and precipitation) prior to disposal.

In spite of the demonstrated destruction capabilities of hazardous waste incinerators and the apparent low incremental risk of emissions, there

is considerable public opposition to sitting and permitting these facilities. Permits for commercial Hazardous Waste Incinerators require an average of three years, and often much longer, to be finalized. Uncertainty over permitting and public acceptance will likely result in a near-term shortfall in needed capacity for certain geographic areas and for specific waste types such as explosives, mixed waste, and possibly solids and sludge (Dempsey and Oppelt 1993).

Incineration is thus far best demonstrated available technology for waste destruction. Unfortunately, it is not a perfect technology. It may emit unwanted Products of Incomplete Combustion (PIC) or trace metals. However, the amounts of the PICs in the exhaust are generally at least two orders of magnitude less than the original compounds in the feed. Both PIC and trace metal emissions are very complicated problems (Lee, Huffman and Oberacker 1986). Therefore, a considerable amounts of research needs to be done in order to ensure that they can be adequately controlled.

The characteristics of the waste fed and the residues/ash that resulted after incineration were identified through the BeeA'h facility's laboratory. Comparison of these data showed some change in Sulfur and Chlorine parameters. Also, comparison of the ash Solids and Some of Toxicity Characteristic Leaching Procedure (TCLP) regulatory levels showed that increase in Cadmium, Chromium, and Lead parameters, however; Arsenic and Mercury were below the regulatory levels. This suggests that, the residuals may require further treatment (such as stabilization and precipitation) prior to final disposal.

The types and quantities of air pollutants emitted from the BeeA'h incinerator were compared to the air quality standards, and emission standards and found that CO and SO_2 parameters were within the standards.

A special study was performed for the subject incinerator which a one sample was collected from the waste feed before incineration, and one samples of the ash material after incineration was also collected for a one-time analysis. This was analyzed in a different laboratory other than BeeA'h Co. The reason for this, is to compare the results with the BeeA'h company laboratory results and to perform the material balance for the subject incinerator. Results showed that some change in some parameters such as; pH, Loss on Ignition, Moisture Content, Chloride, Potassium, Silica, Sodium, Sulfur, Arsenic, Mercury, and Zinc.

As mentioned, the special sample that was collected on 22 December 1999 from BeeA'h incinerator for a one-time analysis was used to conduct the material balance. The purpose of material balance calculations is to determine inputs and outputs of a system. There was a difference in the material balance and that could be related to the accuracy of the diesel fuel consumption in the subject incinerator or the analysis of loss of ignition.

7. SUMMARY

Increased concern has been expressed in recent years with regard to potential contamination of the environment as a result of the operation of municipal and chemical waste incinerators. As a result, there has been a significant modification of waste management practices.

Incineration is an engineering process that employs thermal decomposition via thermal oxidation at high temperature that usually 900°C or greater, in order to destroy the organic fraction of the waste and to reduce the volume. Of all of the permanent treatment technologies, properly designed incineration systems are capable of the highest overall degree of destruction and control for the broadest range of hazardous waste streams.

The National Environmental Preservation Company (BeeA'h) was selected to perform this study. It is a fully Saudi owned company established in 1988 to manage the disposal of industrial generated hazardous waste. It is located in Jubail Industrial City, Kingdom of Saudi Arabia.

On 1997, BeeA'h has invested in a rotary kiln type incinerator with air emission control systems to meet air emissions standards known as the Hazardous Waste Incineration Facility.

The main objective of this study is to determine the environmental impact of incinerated hazardous waste. The specific objectives are concentrated on impact on the air quality and the types of residues (ash) that are generated through incineration process. Data were collected from BeeA'h for nine months period for air emissions, waste feed, and residues (ash).

The types and quantities of air pollutants emitted from the incinerator were identified. Data were collected from BeeA'h Co. Findings were compared to emissions and air quality standards. Comparison of average results of nine (9) months period between Stack Emissions (Gas Concentrations) and air pollution source standards showed that CO and SO_2 parameters were within the standards.

The types, quantities and characteristics of the waste fed and the residues (ash) resulted after incineration were identified through laboratory analysis at the facility. Comparison of average results of nine (9) months period between incineration waste fed and residues (ash) after incineration showed change in Sulfur and Chlorine concentrations. Also, comparison of the average results between residues (ash) and some of Toxicity Characteristic Leaching Procedure (TCLP) regulatory levels showed that increase in Cadmium, Chromium, and Lead concentrations, however; Arsenic and Mercury were below the regulatory levels.

Special experiment was performed for the mentioned incinerator that a one sample was collected from the waste fed before incineration, and one sample of the ash material after incineration for a one-time analysis. This is in order to, analyze for selective chemical and physical analysis parameters. Comparison of results between incineration waste fed and ash showed that some change in Loss on Ignition level, and change in some concentrations such as; pH, Moisture Content, Chloride, Potassium, Silica, Sodium, Sulfur, Arsenic, Mercury and Zinc. In addition, the material balance was calculated to provide an analysis of the subject incinerator system inputs and outputs.

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